NORTHWESTERN UNIVERSITY

Examining Women-in-Computer-Science Groups as a Means for Diversifying STEM: A Cross-Level Analysis

A DISSERTATION

SUBMITTED TO THE GRADUATE SCHOOL

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

for the degree

DOCTOR OF PHILOSOPHY

Field of Learning Sciences

By

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EVANSTON, ILLINOIS

December 2021

Abstract

The gender imbalance in computer science is getting worse, with computer science being the only Science, Technology, Engineering, and Mathematics (STEM) field in which women's representation has steadily declined throughout the past few decades. Rectifying this gender imbalance is an urgent need, both because of fundamental issues of equity and because leaving most women out of the labor market in computer-related industries dramatically lowers the number of American workers to fill these roles. Although many efforts have proved to be effective in increasing women's participation in computer science, many of those may be difficult to replicate on a large scale, as they relied on a great deal of investment of time and money from high-level administrators. Therefore, it is worthwhile to consider alternatives.

My dissertation focuses on one attempt to redress the lack of women in computer science—Women-in-Computer-Science (Women-in-CS) or Women-in-Computing (WiC) college clubs. Drawing on organizational change theories, I ask: What are some characteristics of the Women-in-CS clubs and how do students engage them? Do they engender changes? If so, how? I explored these research questions through two theoretically connected but methodologically different studies, using thematic network analysis and ethnography respectively. Through a cross-level analysis, I argue that Women-in-CS clubs' mission statements and practices directly speak to the challenges of gender inequality in computer science. For students, Women-in-CS club is an identity, a community, a safe space, and the beginning of a career-long practice of mentoring future women in computer science. Moreover, changes driven by such clubs have brought

impacts to both the individual level female computer science students and the organizational level computer science departments. Both top-down and bottom-up leadership approaches have been used by these clubs to overcome resistance and obstacles related to social cognition and cultural and institutional theories of change. Furthermore, design principles have been derived and identified to shed light on best practices for college clubs with similar goals. This dissertation offers a new perspective on applying organizational change theories in the context of college clubs and contributes to the broader research community on diversity, equity, and inclusion in higher education.

Acknowledgement

There are many who helped me along the way on this journey, and I want to take a moment to thank them.

First and foremost, I would like to express my deepest appreciation to my PhD advisor and the chair of my dissertation committee, Prof. David Uttal, for all the guidance and advise during the past six years of my PhD study. I have always enjoyed our weekly meetings where he has been not only knowledgeable but also humorous. None of my accomplishments would be possible without his insights, patience, and encouragement. I would also like to extend my gratitude to other members of my dissertation committee, Prof. Bennett Goldberg and Prof. Eleanor O'Rourke, for always giving me constructive feedback and relentless support on my research. The completion of my dissertation would not have been possible without the support and nurturing of them. Besides my dissertation committee, I must also thank Dr. Sarah Hokanson and Dr. Kinnari Atit, who I had great pleasure of working with on other projects during my graduate study. I am grateful for the opportunities to work with them and the insightful suggestions they have given me along the way. And I also wish to thank Mary Alukos, who offered lots of helpful feedback on editing and polishing of this dissertation.

I want to thank all the current and former members of the Uttal Lab, as well as the Research in Higher Education, Training, and Evaluation team. I appreciate the time spent together with all of them, which has strengthened my sense of belonging at Northwestern University. Thanks should also go to all the faculty and friends at SESP, who have never wavered in their support and have provided a safe space for me. I would like to extend

my sincere thanks to all the students I have worked with for my research projects throughout my graduate study. I would not have been able to complete any of my research without their participation and contribution.

Lastly, I would like to thank my family and friends for their many years of love and belief in me. I would not have gone this far these without my friends' cheers and company, whether these wonderful souls are in Evanston or in other places around the world. I am forever grateful for my parents' as well as my parents-in-law's care and support. The most special and important thanks to my husband, Siyan Dong, for all his love and support along this journey and the many years to come. Finally, a special acknowledgement to my best dissertation writing companion—the baby girl who is still in my belly at this moment but will arrive in this world in just a few weeks. Thank you all. I love you all.

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Chapter 1: Introduction

The Problem: Few Women Participate in Computer Science

There are many more men than women in the field of computer science (CS) (e.g., Cohoon & Aspray, 2006; Margolis & Fisher, 2002). And the gender imbalance is getting even worse; computer science is the only STEM field in which women's representation has steadily declined throughout the past few decades (Cohoon & Aspray, 2006; Corbett & Hill, 2015). Before the mid-1980s, more than 35% of CS bachelor's degree recipients were women (NCES IPEDS, 2015). By 2017, the percentage had fallen to 19% (NCES IPEDS, 2018). In the same year, only 22% of the PhD recipients in computer science were female (NCES IPEDS, 2018). Despite the low representation of women in computer science, the overall undergraduate computer science enrollments have risen substantially in the last decade (National Academies of Sciences, Engineering, and Medicine, 2018; Zweben & Bizot, 2018). Even so, American universities and colleges are still not producing enough graduates in computer science to meet expected demand (Microsoft Corporation, 2012). Therefore, we need to rectify this gender imbalance, both because of fundamental issues of equity and because leaving most women out of the labor market in computer-related field dramatically lowers the number of American workers to fill these roles.

Many studies have examined the causes of the underrepresentation of women in computer science at the college level. Some consistent findings are as follows: First, women enter college with substantially less computer experience, on average, than their male counterparts (Mounfield & Taylor, 1994; Parelius & Sackrowitz, 1996; Scragg &

Smith, 1998; Margolis & Fisher, 2002). Second, there is a lack of mentoring opportunities for women, and an associated lack of confidence and interest in their computing abilities (Irani, 2004; Jepson & Perl, 2002). Third, a male-dominated culture of computing and the notion that men are mathematically superior and innately better suited to STEM fields makes women feel less connected to the field (Dryburgh,2000; Gürer & Camp, 2002).

Redressing the Problem

How can the problems that limit women's participation in computer science be redressed? Many approaches have been tried to address the large gender discrepancy in computer science, and some efforts have been successful.

For example, there are many competitions and summer camps focusing on increasing girls and young women's interest in computer science (e.g., ProjectGirls, Tech Trek, Girlstart Summer Camp). Such programs create an equal learning environment for female students so that these students' interest in computer science can be increased and their skills can be better developed in preparation for college courses. As a result, female students will not be turned off by introductory level computer science courses that are often considered "weed out" classes.

Moreover, some efforts have been made to redefine the field of computer science so that the structure of the curriculum becomes more friendly to female students with less programming experience. For instance, Harvey Mudd College redesigned their introductory computer science course to focus on creative problem solving and

opportunities within the field, rather than a traditional pure programming course. Harvey Mudd also made classes less intimidating by splitting the course into two sections based on incoming students' prior programming experience. Such efforts to redefine computer science courses cultivated a supportive culture and environment and resulted in a substantial increase of percentage of female students in computer science (from 10% to 40%) in just four years at Harvey Mudd College (Alvarado & Dodds, 2010; Alvarado et. al., 2012).

Furthermore, many universities have designed research experience programs or learning communities that target specifically on undergraduate female students in computer science. Examples of such programs or communities include Carnegie Mellon University's OurCS program (Menzel & Frieze, 2018), Indiana University's HelloResearch program (Menzel et. al., 2019), and Rutgers University's CS Living-Learning Community (Wright et. al., 2018; Wright et. al., 2019). These programs created opportunities for students to work with faculty members, and the mentoring from faculty members, especially from female role models, could instill confidence in young women pursuing careers in traditionally male-dominated fields such as computer science (Menzel et. al., 2019; Wright et. al., 2018).

There are also many organizations and corporate programs providing mentorship for women in computer science for the same end. For example, Built By Girls has a WAVE program where they connect young women with professionals in tech for 1-1 mentoring. Large tech companies, such as Google or Apple, also have mentoring

programs in which female employees in the industry are paired with college students to offer suggestions and advice.

Although many efforts have proved to be effective, these efforts may be difficult to replicate on a larger scale, as they relied on a great deal of investment of time and money from high-level administrators. When there is change in leadership or when funding from external agencies ends, many of these programs might not be able to sustain and continue the change they have already started. Thus, while these efforts are outstanding, they are not without limits, and it is worthwhile considering alternatives.

Women-in-Computer Science Clubs

This dissertation focuses on one attempt to redress the lack of women in computer science that may provide some of the same benefits as these prior efforts but is substantially less expensive and hence more likely to scale. Specifically, this dissertation focuses on what are commonly called *Women-in-Computer Science (Women-in-CS)* or *Women-in-Computing* groups. There are many Women-in-CS groups in both universities and corporate settings. Most of these groups are self-organized, with the goal of increasing participation of women in the field of computer science and building a community for these women. These Women-in-CS groups often organize various programs, such as technical events that focus on computer science skills, career development events that help students prepare for internships and jobs, and community building events that bond all the women together. Research has shown that participating in extracurricular activities that help socially connect students with peers can lead to better retention (Mahoney & Cairns, 1997). Extracurricular activities, especially

experiential educational activities, can help to keep students, and especially underrepresented students, in STEM fields, by boosting students' academic engagement and skill mastery, sense of belonging, and confidence (Djonko-Moore et. al., 2018; Hunter et. al., 2007; Lapatto, 2007; Nyame-Mensah, 2015; Russell et. al., 2007).

This dissertation is an attempt to fill the gap in the literature concerning learning and organizational change for women in computer science. To my best knowledge, there is little research that has studied Women-in-CS student groups thoroughly as a way to broaden participation, let alone applying an organizational change perspective to analyze and interpret the impacts of such groups. With an aim to address the larger question of how we can design better organizational interventions to broaden women's participation in computer science, or in STEM in general, the primary questions that guide this inquiry are the following: What are some characteristics of the Women-in-CS organizations? How do students engage in these organizations? Are these organizations helping women in persisting and succeeding in the field? How can we design organizations and learning environments that increase women's representation in the field of computer science?

A first step to answering these questions is to understand the current state of women in computing organizations. Specifically, I focused on undergraduate Women-in-CS clubs at a number of universities across the U.S. With a better understanding of the current status of the women in computing groups at the university level, as well as its potential obstacles and opportunities discussed in the first part of the study, the second part of my research focuses on designing and identifying effective practices for such organizations in an empirical setting of a specific undergraduate women in computing

club. Specifically, I am interested in exploring how the design of the organization helps female students to succeed and persist in computer science by looking at the growth of female computer scientists at the individual level and the growth of women in tech community at the organizational level.

This dissertation consists of six chapters. This chapter, Chapter 1, is the introduction chapter. Chapter 2 is a literature review on existing research on individual and organizational factors relating to women's success in computer science, along with my theoretical motivation for conducting this research. Next in Chapter 3, I discuss my converging methods for cross-level data collection and analysis. In Chapters 4 and 5, I present findings and results from my two studies respectively, including a network analysis and a multi-year field study with a University Women-in-Computing club. Chapter 6 is discussion, limitations, and future directions, in which I conclude my dissertation research and identify the expected contributions of my dissertation to the study of women in computer science and organizational change.

Chapter 2: Theoretical motivation and literature review

The ultimate goal of this dissertation is to identify ways in which the representation of women in computer science can be increased. This is fundamentally a question about organizational change. Therefore, I have grounded the theoretical motivation of my work in terms of organizational change theories. Of course, aspects of the organizational impact will play out at the level of the psychology of the individuals. For example, if there is a tendency for organizations to discriminate against women, then this may show up in terms of women having low sense of belonging or low self-esteem if they are in computer science programs. Ultimately then, both to understand the causes of the low representation of women and to redress the problem, we must examine this problem at both the organizational and individual (psychological) level.

Figure 1 is a representation of my theoretical perspective on organizational level and individual level factors that contribute to the imbalance of gender in computer science. In this figure, I have included some of the relevant variables that have been identified at both the organizational and individual level. As illustrated in the figure, the group level is the level between organization and individual, and it bridges the changes between organizational and individual levels. In this dissertation, the group level is represented by women in computer science groups, and I analyze the corresponding causes and changes at both organizational and individual level.

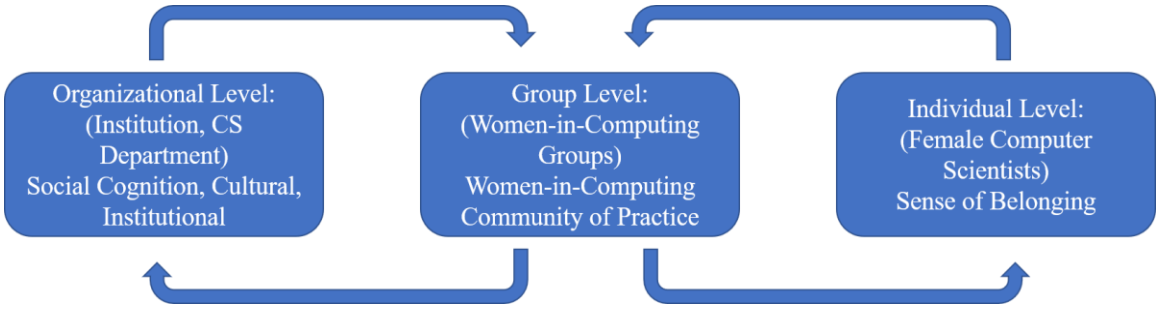


Figure 1: Cross-level Analysis on Women-in-Computer Science Clubs

Organizational Level and Organizational Change

The initial theoretical motivation for my dissertation begins with a consideration of organizational factors with regards to changes in women's representation in computer science.

Kezar (2013) proposed six theories and models in terms of organizational change in higher education; they are scientific management, evolutionary, cultural, political, social cognition, and institutional. Among these theories of change, I find three particularly relevant to the context of this dissertation: social cognition, cultural, and institutional, which corresponds to the three levels (individual, group, and organizational) that I have identified earlier in the context of Women-in-CS groups.

Social Cognition Theory of Change

Social cognition theory highlights the role of individual learning and development and assumes that change can be best understood and enacted through individuals (Harris, 1996; Kezar, 2001; Martin, 1992). The focus of change is to shape individuals' thinking and interpretation within the organization. Change occurs because individuals see a need to grow, learn, and change their behavior. In the context of this dissertation, social cognition theory can be best understood as change at the individual level. For instance,

the Women-in-CS groups may help members to realize that they themselves also need to grow and improve to succeed in such a male-dominated field. They learn technical skills and professional development skills through participating in women in computer science groups' events. And then the better individuals become a better community and that can eventually lead to increased representation of women in computer science. Moreover, social cognition change in the context of Women-in-CS groups can also involve changes in motivations and identities at the individual level, which could be change in self-efficacy or change in sense of belonging.

Cultural Theory of Change

Cultural theory of change suggests that cultures are always changing, and change occurs naturally in the form of changing values and beliefs (Kezar, 2013; Morgan, 1986; Schein, 1985; Shaw & Lee, 1997). Cultural theory of change involves change at multiple levels and in different forms. In the context of this dissertation, cultural theory of change can be best understood as the bridging role that women in computer science groups play between the individual and the organizational level. For example, the women in computer science groups' executive board organize events such as mock interviews and hackathons to facilitate individual learning of the members. The executive board also frequently connects to faculty members and department chairs in computer science, to seek for change in environment and departmental culture.

Institutional Theory of Change

Institutional theory of change examines the impact of the broader societal field such as nation-state. It takes into consideration both internal organizational features as

well as external conditions that may cause change to happen. In the context of this dissertation, institutional theory can be best understood as the nationwide effort of broadening participation of women in computer science and how each institution or organization enacts such effort. And therefore, the institutional theory of change can be used to examine change at the organizational or even higher level(s). For example, Northwestern University's McCormick School of Engineering and its Computer Science Department devote considerable effort to funding female students in computer science to go to the annual Grace Hopper Celebration—the largest gathering of women in tech in the world. This creates opportunities for female computer science students to connect with role models in the field and get internships or even full-time jobs. Such efforts in turn might inspire more females to stay in computer science and pursue a career in this field.

By integrating these theoretical perspectives, my dissertation seeks to examine women in computer science groups at the individual, group, and organizational level and to understand how and why these groups can help broadening participation of women in computer science through the lens of organizational change.

Individual Level Psychological Factors

As mentioned before, many of the organizational level obstacles and impact could manifest at the individual level, and one factor that seems to be the most important to this dissertation is sense of belonging or sense of community. Women stay in the field if they feel they belong, and they leave when they feel not being part of the community (Lewis, et. al., 2017).

Sense of Belonging

Perhaps the most important psychological factor is *sense of belonging*. This entails the feeling that one fits in, belongs to, or is a member of a community. Sense of belonging can also entail the feeling that one feels valued, accepted and recognized by other members in the community. The key aspects of sense of belonging include membership, shared emotional connection, fulfilment of needs, and opportunity to have influence (McMillan & Chavis, 1986; Osterman, 2000).

It is well documented that the need for belonging is a basic human motivation (Baumeister & Leary, 1995; MacDonald & Leary, 2005) and has been recognized as an important driver of physical and psychological wellbeing (Bolger et. al., 2000; Hawkley & Cacioppo, 2010; Maslow, 1968; Spiegel et. al., 1989). Sense of belonging has also been indicated as a key factor of academic achievement in many recent studies (Cohen & Garcia, 2008; Good et. al., 2012; Walton & Cohen, 2007).

Sense of Belonging and Academic Achievement. Students who report feeling more connected with their school community also report liking school more (Solomon, Battistich, Kim, & Watson, 1996), which means that sense of academic belonging is positively correlated to attitude toward schooling. Moreover, sense of belonging has also been linked with outcomes directly related to achievement. For example, sense of belonging is positively correlated with self-efficacy, academic competence, academic performance, and even retention rate (Zumbrunn et. al, 2014; Bandura, 1982; Pittman & Richmond, 2007; Hausmann et. al., 2007).

Sense of Belonging in a Specific Academic Domain. In considering academic success, sense of belonging is often measured in a specific academic domain. For example, sense of belonging is measured specifically in regard to math, physics, or some other fields. Research has shown that sense of belonging in a specific academic domain is positively correlated with academic outcome in that domain, including persistence and retention in the domain. When individuals feel that they do not belong, they are more likely to opt out of the domain to pursue studies and professional goals within a different discipline that better enables this sense of belonging to take root. This is especially true for women in underrepresented fields such as STEM. For example, Seymour and Hewitt (1997) suggested that a common reason for women to leave science majors was they felt like they were outsiders in the traditionally male-dominated science fields (Seymour & Hewitt, 1997). Similarly, London and his colleagues found that women who reported feeling less sense of belonging in their specific STEM majors were more likely to expect to leave the field (London et. al., 2011).

Studies have also examined sense of belonging in computer science in particular. For example, Lewis et. al. (2019) reported that the alignment of students' communal values and their perception of the affordance of computer science to fulfill such values is an important predictor of students' sense of belonging in computing. Besides alignment of goals and perceptions, enrollment policies in computer science departments also predict students' sense of belonging in computing, especially for first-year students, and the effect was found to be negative (Nguyen & Lewis, 2020). Moreover, both student characteristics and experiences in introductory courses have been shown as important

predictors of sense of belonging in computing for women and underrepresented minority students (Sax et. al., 2018). Therefore, based on evidence provided in the literature, it is reasonable to believe that sense of belonging might be a possible cause for women's underrepresentation in the field of computer science.

Sense of Belonging and Stereotypes of Ability. Many studies have documented stereotypes that suggest that women are not as talented in STEM fields as men are and the negative consequences associated with these stereotypes (Dar-Nimrod & Heine, 2006; Good et. al., 2008; Nosek et. al., 2002; Spencer et. al., 1999; Steele, 1997; Steele & Aronson, 1995; Inzlicht & Ben-Zeev, 2000). This important line of work has highlighted how negative stereotypes can undermine women's academic performance. However, negative stereotypes affect more than academic performance; they may also result in women's lower sense of belonging in STEM fields. Women would feel less valued and accepted in these fields and might decide to leave the fields, which then results in the underrepresentation of women in STEM fields. For example, women felt less belonging when they felt they were perceived as less talented and less abled than peers in STEM by others. In contrast, when women believed that everybody had to put in a high amount of effort to succeed in STEM, they would feel more sense of belonging (Dweck, 1986; Good et. al., 2012; Leslie et. al., 2015; Smith et. al., 2013). The exact mechanism linking ability stereotypes and decreased sense of belonging is still unclear at this point. However, what we can expect based on the reasoning is that fighting against ability stereotypes would possibly lead to increased sense of belonging. Therefore, it is reasonable to believe that WiC's events that focus on improving women's tech skills,

such as hackathon, study hours, and other tech events, could potentially increase women's sense of belonging in computer science. Through participating in these events, female students might see other women succeeding in computer science, despite the prevailing stereotypes, and therefore feel more valued and accepted in the field of computing.

Group Level: Women-in-CS Student Groups

Student groups, or college clubs, are nothing new in higher education. Besides involvement in classes, student groups might be one of the most major ways of students' involvement on campus.

Student Groups and Students' Learning and Development

Research has suggested student involvement to be a statistically significant contributor to desired outcomes of college student learning and development, both cognitively and psychologically ((Astin, 1977, 1984, 1993, 1996; Moore et. al., 1998; Terenzini et. al., 1996). For college student groups in particular, Foubert and Grainger (2006) found that college students who were involved in student groups had consistently higher psychological development scores compared to uninvolved students. The degree of involvement in student groups was also found to be positively related to development—those who joined or led student groups reported more development than those who just attended club events (Foubert & Grainger, 2006). In another study in a community college setting, Derby (2006) revealed that involvement in student organizations had significant relationships with degree completion, student retention, and

persistence across time. Therefore, prior research indicates that student groups can improve students' experience. Although little or no research has specifically looked at Women-in-CS groups, these groups are likely to have positive impacts on students, based on existing research on student groups and students' learning and development.

Women-in-CS Groups as a Community of Practice

As suggested above in Figure 1, the group level is the level between the individual and the organization, and it serves as the bridge that reflects changes at both levels. In my dissertation, I treat women in computer science groups as part of the group level. Such groups can be considered a STEM community of practice. A community of practice is a group of people who form a community for a shared concern or passion for something they do as they interact regularly (Allee, 2000; Lave, 1988; Wenger, 1998). Wenger (1998) proposed three main characteristics shaping community of practices: mutual engagement, a joint enterprise, and a shared repertoire.

Mutual engagement is the shared involvement of the various members of a group, their relations, and their working together. In the context of women in computer science groups, there is mutual engagement as members gather almost weekly to attend various events organized by the group. Such events allow them to work together on a common project, in the same space. A joint enterprise is a common aim and shared understanding that binds the members of the community together and is constantly renegotiated to fit the members' individual aims. In the context of women in computer science groups, there is a joint enterprise stated in their mission statement that "help(s) them foster a sense of belonging and solidarity, and leave(s) them proud and excited to be women in tech (from

Northwestern's Women-in-Computing website)." A shared repertoire is a set of coherent concepts, resources, and especially methods shared among the members of the group. In the context of women in computer science groups, this shared repertoire can be the concepts of computer science knowledge and methods, as well as the resources for internship and other opportunities.

Women-in-CS Community of Practice for Experiential Learning. People learn best through experience. Experiential learning has proven to be a powerful teaching and learning approach since the 20th century (e.g., Dewey, 1938; Kolb, 1984; Piaget, 1964). Experiential learning covers a broad range of activities such as lab, internship, and field study, and many of these activities are exactly the type of activities that women in computer science community of practices often organize. For example, every year Northwestern's Women in Computing group, together with the School of Engineering and Computer Science Departments, fund approximately 50 female students to go to the Grace Hopper Celebration as an experiential learning trip. This experiential learning activity has been carried out at Harvey Mudd College for many years and has proven to be effective in female students' engagement and retention in computer science (Alvarado et. al., 2012; Alvarado & Judson, 2014). However, it is still not quite clear with regards to the mechanism on why such experiential learning activity by a community of practice might work.

Women-in-CS Groups and Tight-Loose Cultures

As organizations, Women-in-CS groups have their own cultures. One way to examine organization cultures and the role of cultures is to look at how strictly different

cultures enforce norms, which is also known as tight or loose cultures (Gelfand, 2018). According to Gelfand (2018), tight or loose cultures at different levels affect how people behave, and both tight and loose cultures have their own advantages and disadvantages. On the one hand, tight cultures are more coordinated and uniform, and have more requirements. People in tight cultures also tend to have more self-control. On the other hand, loose cultures are found to be much more open—they are more open to new ideas (more creative), to new people (they're less ethnocentric), and to change (Gelfand, 2018). Thus, thinking about the tightness or looseness of CS clubs for women may help to shed light on leadership roles, organizational change, and impacts of Women-in-CS groups.

Connecting Organization and Individual through the Group Level of Analysis

As mentioned before, this dissertation aims to examine the effectiveness and the mechanism of increasing representation of women in computer science through women in computer science groups at both individual and organizational levels. Since the core concept at the individual level is sense of belonging, I now review the organizational factors including environment and culture that can influence individual's sense of belonging.

Stereotypes and the Physical Environment

The physical objects in an environment serve as cues about who belongs there because they can signal the culture of the people associated with that environment (Cheryan et. al., 2009; Kesebir et. al., 2010). People often self-check their sense of belonging by interpreting the cues in the environment (Murphy et al., 2007; Schmitt et. al., 2010). When people perceive a mismatch between the stereotype of the environment

and their own perception of what kind of people they are, they would feel less sense of belonging (Cheryan et al., 2009; Stephens et. al., 2012). Cheryan and colleagues (2009) found that women felt less sense belonging and less interested in computer science when they were exposed to an environment that contained more physical objects that fit with computer science stereotypes (e.g., a Star Trek poster, computer parts, technical programming books), compared to an environment with neutral items (e.g., nature posters, general interest books). In contrast, men's sense-of-belonging and interest in computer science was not affected by the environment. This was because the stereotypes associated with computer science are often more compatible with the male gender role. The relationship between physical environment and stereotypes in computer science may reflect a general trend of adolescence and emerging adulthood. For instance, Master et. al. (2015) found that physical environment with cues indicating girls are welcome increased girls' self-reported interest in computer science, and that intentional redesign of the classroom could encourage girls to enroll in computer science classes. Women's sense of belonging, therefore, can be increased by creating an environment that counteracts prevailing stereotypes of the field for them.

Many women in computer science groups have been trying to shift the social environment toward one that is more welcoming and friendly to women by building a community, and this is rooted in the mission statements of many of these groups. For example, Stanford's WICS works to "promote and support the growing community of women in CS and technology"; Women@SCS at Carnegie Mellon University "promotes the breadth of the field and its diverse community". However, to my knowledge, a

thorough analysis of the existing women in computer science groups is still missing in the current literature.

Peers and Role Models

Both ethnographic and lab studies have suggested that lack of peers and role models might result in low sense of belonging. For example, Seymour and Hewitt's ethnographic study on why women leave STEM fields found that low sense of belonging of women in STEM fields stemmed from the isolation resulted from having few same-gender peers in their departments (Seymour & Hewitt, 1997). Similarly, Murphy et. al.'s (2007) lab study also led to the same result. They showed participants a video featuring a STEM conference where the number of women in a group was systematically manipulated. Their results showed that women who watched the video with women underrepresented in the conference felt less sense-of-belonging and less interested in attending the conference, compared to women who watched the video with a more balanced gender representation. Researchers also proved that interacting more with female peers and instructors has proved to be beneficial in boosting female students' sense of belonging in math (Stout et. al., 2011). Therefore, in computer science departments, in which only about 1 in 5 people are women, seeing very few female peers and role models could lead women to believe that they do not belong here.

In addition to the number of women and the presence of role models, the type or kind of role models also matters. Cheryan and colleagues (2013) studied whether role models would affect women's interest and sense of belonging in computer science. They found that women's sense of belonging differed by the type of role models available.

Specifically, women reported the lowest sense of belonging and decreased interest in pursuing a computer science major when the role model they interacted with fit with the typical computer science stereotypes, such as being socially awkward and geeky. Interestingly, this result was gender-neutral, meaning that it held regardless of whether the role model was male or female. Similarly, Chen and Hamilton (2015) showed that perceptions of diversity are not only driven by the numeric representation of minorities, but also by the social acceptance within a group, in both academic and business settings.

Therefore, to foster a stronger sense of belonging for women, we need to not only work on increasing the number of STEM peers and role models, but also changing the characteristics of the environment in which they interact with peers and role models. Many women in computer science groups have programs that connect young female students with female faculty in computer science or senior peers, and based on the reasoning these groups could potentially address the issue of peers and role models at the organizational level and result in an increased sense of belonging at the individual level.

Guiding Questions of the Current Study

So far, I have illustrated why my dissertation attempts to look at Women-in-CS groups as a potentially important means of increasing participation of women in computer science: I think they have the potential to substantially reduce the gender imbalance in Women-in-CS. In addition, these groups represent a natural bridge between the organizational level and individual level from an organizational change perspective.

Because very little research, to my knowledge, has studied Women-in-CS organizations thoroughly, an overview of these groups at a larger scale is needed to ground this work in the computer science education research community. Therefore, the first question I address is this: What are some of the important characteristics of the Women-in-CS organizations? What is the current status of such groups nationally? How are these groups organized? How do they function? How do they reflect the organizational theories?

Then, because my goal is to analyze Women-in-CS groups across organizational, group, and individual levels, I situate the work in a specific Women-in-CS groups at a university setting. Specifically, my research questions for this particular group are the following: How do women engage in these Women-in-CS groups? How do computer science departments and the field of computer science respond to such groups? Are these groups helping women to increase their sense of belonging in computer science and changing the computer science culture, so that the imbalance of gender in computer science can be addressed?

Moreover, although these groups are often self-organized and self-sustained, it is still very important to generate design principles from the successful Women-in-CS groups so that Women-in-CS groups can be intentionally better designed to increase women's representation in the field of computer science. Therefore, a thorough reflection and discussion to derive design principles from both the network analysis of the nationwide Women-in-CS groups and the in-depth ethnographic research at a university setting is needed to provide insights on design principles of such groups at a larger scale.

Taken together, the overall goal of my dissertation is to explore Women-in-CS groups as an alternative to broaden participation of women in computer science and derive design principles from successful existing groups so that we can better design organizations and learning environments in the future.

Chapter 3: Converging Methods

As discussed before, the main goal of this dissertation is to explore Women-in-CS groups as an alternative to broaden participation of women in computer science and understand the impact of Women-in-CS groups on individuals and organizations. Therefore, a multi-step, mixed-method, and cross-level approach is needed to fulfill my goal. Specifically, in this dissertation, I investigated Women-in-CS groups through two studies that are both conceptually related but use very different methods. In Study 1, I conducted a large-scale semantic network analysis of the artifacts (websites) of college level Women-in-CS groups, to gain insights into shared values and practices that are considered important for such organizations. Then, in Study 2, I conducted a multi-year ethnographic study of the Women-in-Computing (WiC) club at a private university in the Midwest by using both quantitative survey method and intensive, qualitative observations and interviews. The observations and interviews were guided and informed by results from Study 1, with a hope to examine whether this WiC club's actual practices reflect their values and practices stated on the website. If so, what does that alignment mean? Or if not, does that mismatch tell us anything? Moreover, one-on-one interviews with the WiC executive board members were conducted to see whether and how participation in WiC facilitate women's engagement, interest, participation, and persistence in computer science. At the same time, these interviews also allowed me to dig into what impact WiC had on the Computer Science Department. Furthermore, a survey on sense of belonging was distributed multiple times throughout the year to provide additional evidence on the relationship between participation in WiC and female computer science students' interest

and engagement in the field. Taking Study 1 and Study 2 together, this work can hopefully provide information on not only the current status of the national level Women-in-CS groups but also details on a particular WiC club in terms of how they function and their impacts at both the individual and the organizational levels.

Study 1: Network Analysis of the Websites of Women-in-CS Groups

The goal of the first study is to explore the current status of the undergraduate Women-in-CS clubs in the country. In the first study of my dissertation, I examined what mission statements are expressed by the undergraduate Women-in-CS clubs; what core programs and events are organized; what ideas and values are highlighted and emphasized; and how clubs, programs, and values relate to each other, respectively. Specifically, I used the mission statements on the groups' websites as an indication of their values and beliefs, and the events and programs as an indication of their practices. I explored whether the values and practices address the challenges of women in computer science identified by previous research. I used text mining and network analysis techniques to make sense of similarities and commonalities.

Study 2: In-depth Study of a Women-in-Computing Group in a College Setting

Although Study 1 can provide description of Women-in-CS clubs' values and practices, all the analyses were based solely on the information from those clubs' websites and no further information is available on what is actually involved in practices and whether the practices speak to the issues of experience, confidence, and culture. Therefore, the second study of an in-depth look at one particular Women-in-Computing

(WiC) group is needed to provide details and nuances of how students actually engage in Women-in-CS clubs and the mechanisms behind the changes they bring. For Study 2, I focused specifically on the practices and values reflected from the websites' network analysis in Study 1 and tried to answer how participation in WiC facilitate women's engagement, interest, participation, and persistence in computer science. Multiple data collection approaches, including observation, interview, and survey, were used to provide evidence and triangulate on the influence of WiC on female college computer science students and on Computer Science department. Finally, design principles were developed based on my results, which can be used to make recommendations to the university administrators.

In summary, Study 1 and Study 2 are two different but complementary projects that together contribute to the larger goal of this dissertation. Study 1 is a large-scale but superficial exploration based on information available publicly on the websites; whereas Study 2 is an intensive deeper-dive investigation on one particular Women-in-CS group that is built on findings from Study 1. With both studies, this dissertation can hopefully uncover some of the "secrets" in these Women-in-CS groups.

Chapter 4: Network Analysis of Women-in-Computer-Science Groups

Women-in-Computer-Science (Women-in-CS) groups, as one type of on-campus college student group or club, have evolved and developed in the past few years across the U.S. Still, up to now, there have been surprisingly few studies of the values embedded in these groups and the practices they enact. Because college student groups could potentially benefit student development, leadership development, and organization development (Derby, 2006; Foubert & Grainger, 2006), all of which may have positive impacts regarding the gender imbalance in computer science, knowing the extent to which Women-in-CS groups align might be crucial knowledge to understand both the current status of Women-in-CS groups and their future development.

The present study aimed to answer the question of the current alignment of Women-in-CS groups with further interpretation regarding the values expressed by these groups and the practices enacted by these groups, as well as the coherence of these groups. The research questions of this study include: What are some characteristics of the Women-in-Computer Science (Women-in-CS) groups? What is the current status of the undergraduate Women-in-CS groups in the United States? How are these groups similar to or different from each other? How do they function?

Specifically, I examined a large collection of mission statements of Women-in-CS clubs. I addressed questions such as the following: what core programs and events are organized; what ideas and values are highlighted and emphasized; and how clubs, programs, and values relate to each other. I used the mission statements on the Women-in-CS groups' websites as an indication of their values and beliefs, and the events and

programs as an indication of their practices. In addition to these descriptive data, I also examined conceptual and practical commonalities and differences among currently existing Women-in-CS groups, as well as interrelations among the various groups. I interpreted my results by situating them in the previous literature and exploring whether the values and practices target the challenges of women in computer science identified by previous research.

Data Collection

The data were publicly available on Women-in-CS groups' websites. I chose to focus on websites because they shed light on how the groups present themselves, what they emphasize and advertise, and how these groups are publicly perceived. The general approach of gathering data involved scraping the website contents of selected undergraduate Women in Computer Science groups in the U.S. My search for the Women-in-CS groups started from the top 50 universities based on US News' ranking of best national universities 2021, which resulted in 52 universities (including ties). On the web-scraped data set, particular attention was paid to Women-in-CS groups' mission statements as well as programs and events. Below are some examples of the Women-in-CS groups' websites.

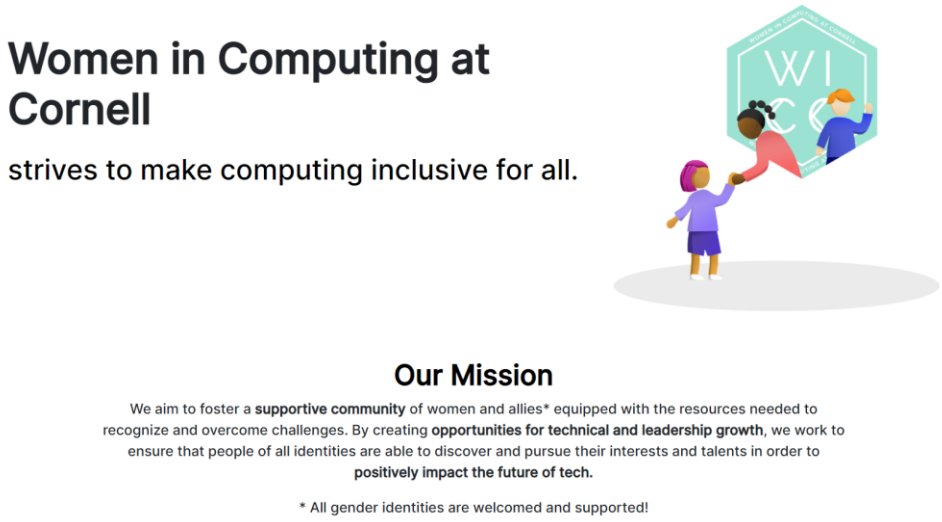


Figure 2: Screenshot of Cornell University's Women-in-CS Website

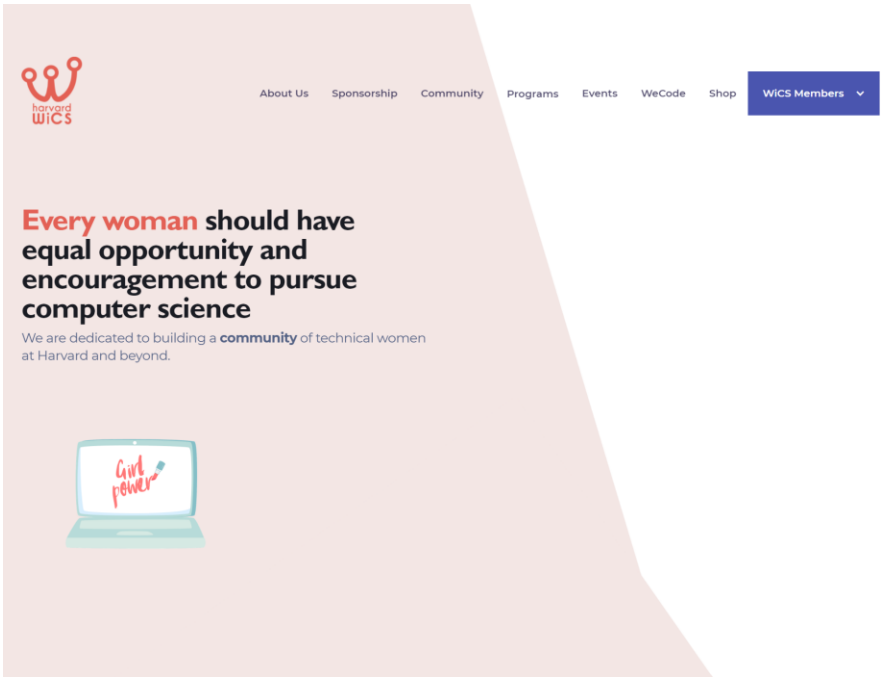


Figure 3: Screenshot of Harvard University's Women-in-CS Website

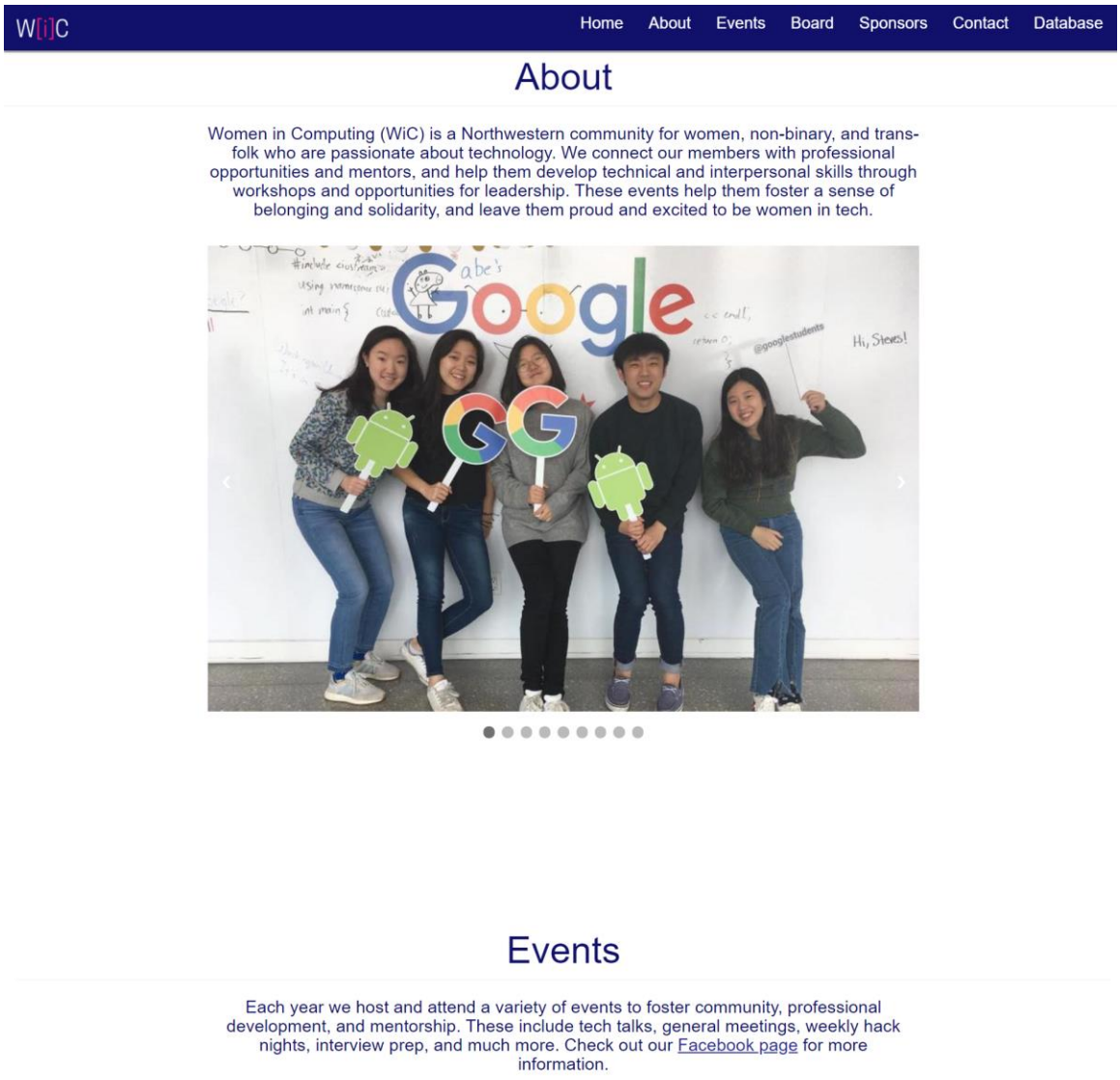


Figure 4: Screenshot of Northwestern University's Women-in-CS Website

Data Analysis

The analysis was accomplished by text mining, standard procedures of qualitative content analysis, complemented by a network analysis approach.

Text Mining on Mission Statements

The purpose of initial text mining on mission statements was to better understand the key elements in Women-in-CS clubs' mission statements and to explore the connections between different Women-in-CS clubs' mission statements. Results from the text mining were then used to guide preliminary coding and the subsequent network analysis.

Preliminary Coding of the Data

Following the steps of skimming, reading, and interpretation (Atkinson & Coffey, 2004), a preliminary document analysis (Bowen, 2009) on the scraped website contents was conducted. This approach was chosen because document analysis is a recommended qualitative research method for studying events, organizations, and programs with rich written content (Yin, 1994).

The preliminary analysis turned the data into categories of values and practices that were ready for the next step's network analysis. Dummy variables for values and programs were created as a result of the preliminary document analysis to represent the presence or absence of each value or program in a particular Women-in-CS club. Organizing data this way ensured the data could then be transformed into matrices that allowed for the network analysis.

Thematic Network Analysis

After the data was organized by the preliminary analysis, a network analysis approach (e.g., Easley & Kleinberg, 2010; Monge & Contractor, 2003) was adopted to find relations among the groups, events, and values, respectively. Specifically, the

approach I took was thematic network analysis. Thematic network analysis is particularly useful in identifying patterns of meaning across a dataset, as well as identifying similarities, differences, and connections. Therefore, this approach is appropriate and helpful in answering my research questions of understanding and interpreting the alignment among Women-in-CS groups.

In this study, I created static network visualization with the *ggnetwork* package and interactive network visualization with the *visNetowrk* package, to showcase semantic networks (e.g., Monge & Eisenberg, 1987) consisting of nodes and connecting edges.

Network Analysis for Connections Between Groups. The first type of the networks was to represent the connections between these Women-in-CS groups based on their mission statements and programs/events respectively. Within each network, the nodes represent the university Women-in-CS groups, and the edges represent their connection based on the common use of certain languages regarding values and practices. The edges are weighted according to the strength of the connection between the nodes, in this case the number of shared events or values. Creating the networks this way allowed me to quickly see how Women-in-CS groups are similar to or different from each other based on what values they stated or what practices they enacted, which then provided answers to my research question of current alignment.

Network Analysis on Values and Practices. In addition to the networks where groups were the nodes, two more networks were created: one on the connections among the various programs and practices and one on the connections among the mission statements. The nodes for these two additional networks are no longer the Women-in-CS

groups per se. For the mission statements and values network, the keywords from their mission statements are represented as nodes and they are defined to be connected when they co-occur in the same Women-in-CS groups. The analogue procedure was used for the program and practice network as well, with nodes being the clubs' practices and events.

These two networks provided information on the core values and beliefs the Women-in-CS groups have and the core events and programs the groups hold, which helps answering the research question with regard to how these groups function. Moreover, creating the networks this way allowed for an intuitive look at the connections among the mission statements and among the practices, suggesting some embedded design and planning considerations of such groups.

Results[1]

In this section, I first describe the final dataset for analysis and then present findings from the text mining on Women-in-CS clubs' mission statements. Findings from the text mining then provide foundations for data visualization and explanation in the next section.

Descriptives of the Data

Among the 52 universities that are on the list of top 50 universities by US News, 42 have Women-in-CS groups, with the earliest founded in the late 1970s. Among the 42

[1] For better display quality of figures in this chapter, please refer to the html file in the supplemental materials.

universities that do have Women-in-CS groups, 2 of them only mention the existence of Women-in-CS groups on the department websites, without dedicated links to the Women-in-CS groups. Therefore, the final data set for analysis includes 40 Women-in-CS groups.

Among the 40 Women-in-CS groups included in the analysis, 26 are from private universities and 14 are from public universities. The most commonly used name for such groups is “Women in Computer Science” - 16 groups named themselves this way. The second popular name is “Women in Computing” - 6 groups named themselves this way. There are also 4 groups that are the official Association for Computing Machinery-Women (ACM-W) chapters. Other naming conventions include “Womxn in Computer Science”, “Women Coders”, etc. The use of “womxn” instead of “women” suggests that some of the groups are using a more inclusive definition of gender and welcome other gender minorities to participate as well.

Text Mining on the Mission Statements

Several tidy text approaches from the *tidytext* package, including co-occurrences and correlations, tf-idf, and topic modeling, were implemented during this stage. Combining these different methods together not only provided information on frequencies, but also the underlying connections and meanings of the text. This text mining aimed to look for mission statements that were related to each other, and/or clusters of similar mission statements.

Most Common Words. After manipulating the data into the preferred form that works with the *tidytext* package, initial simple exploration on the most common words in Women-in-CS clubs' mission statements were conducted. Stop words such as "a", "the", "in" etc have been removed from the analysis because they are meaningless for this exploration.

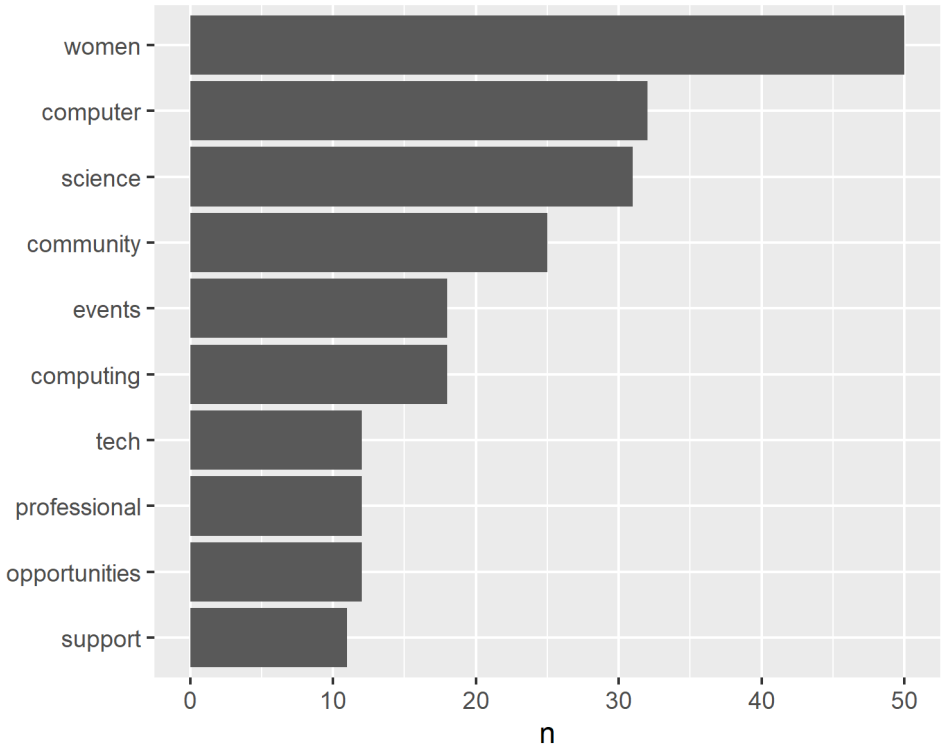


Figure 5: Top 10 Most Common Words from Mission Statements

The figure above shows the top 10 most common words from the Women-in-CS groups' mission statements. Not surprisingly, "women", "computer", and "science" turned out to be the top 3 most common words among all the mission statements, because the mission statements usually start with "XXX(School Name)'s Women in Computer

Science club is a…" Moreover, it appears that "women" is even more common than the other two words, which suggests that such groups have a very strong group identity that they are specifically designed for women. The next set of commonly used words are "community", "events", "computing", "tech", "professional", "opportunities", and "support". Among these words, "computing" is probably less meaningful, as it is just a different way of saying "computer" "science". "Events" and "tech" suggest that these clubs mainly function as organizing events for women in tech. "Community", "professional", "opportunities", and "support" are particularly interesting ones because they suggest that Women-in-CS clubs believe that they are creating a community that supports and encourages women in computer science and organize events for them to provide professional opportunities to help them grow.

Word Co-occurrences and Correlations. As a next step, I examined which words commonly occur together in Women-in-CS clubs' mission statements. A table and a network were created to help us see the relationships better.

Table 1: Word Co-occurrences in Mission Statements

```
A tibble: 8,107 x 3
 item1     item2             n
 <chr>     <chr>         <dbl>
1 women     computer         18
2 computer  science          18
3 women     community        17
4 women     science          16
5 women     events           10
```

```
6 women     computing        10
7 community events            9
8 women     opportunities     9
9 community opportunities     9
10 women     tech             9
# ... with 8,097 more rows
```

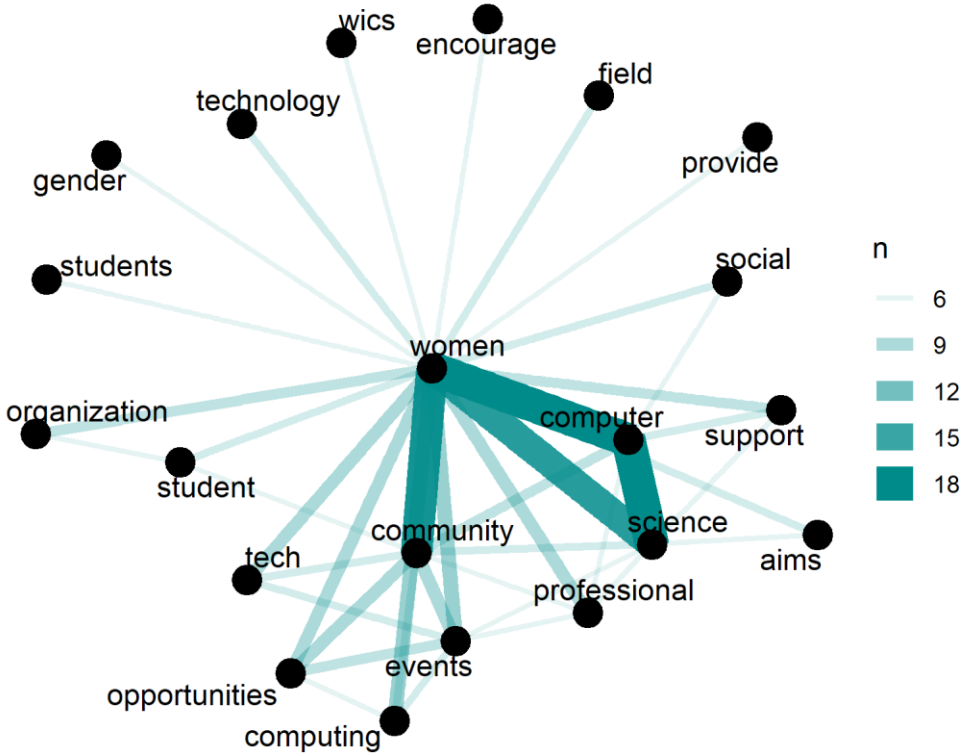


Figure 6: Network of Word Co-occurrences

From the network figure above, we again see clearly that “women”, “computer”, “science” are at the center of Women-in-CS clubs’ mission statements and they co-occur with almost everything. “Community” is also very salient in the center of the network, connecting to other commonly seen words from the previous exploration, such as “opportunities” and “support”. Moreover, this network also suggests some “events” that

might be prevalent in Women-in-CS clubs, such as “social”, “tech”, “professional”, which gives us some clues for the next step’s in-depth analysis on programs and practices.

To examine the relationships among words in the mission statements in a different way, correlation coefficients were calculated and plotted. This looks for those words that are more likely to occur together than with other words for a data set.

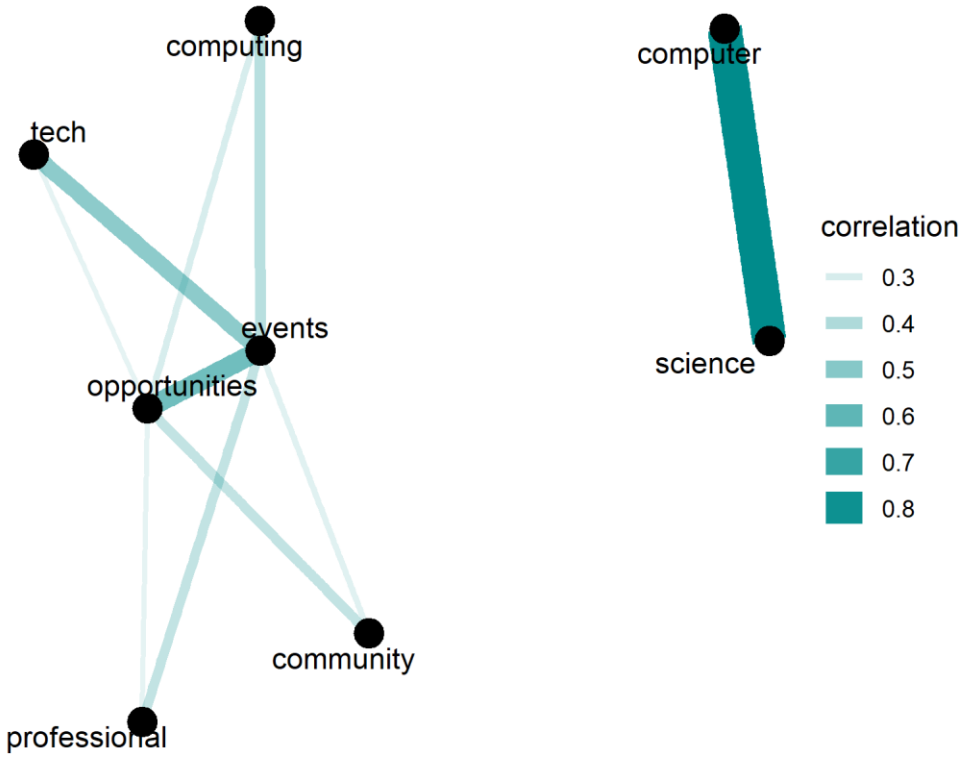


Figure 7: Network of Word Correlations

The figure above appears much different than the co-occurrence network, because the co-occurrence network asks a question about which word pairs occur most often, and the correlation network asks a question about which word occur more often together than

with other words. Despite the different layouts, the keywords we see here are still consistent with the findings from the previous explorations.

Calculating tf-idf. Tf-idf, the term frequency times inverse document frequency, is a very useful measure to identify words that are especially important to a document within a collection of documents. The network graphs above suggest that Women-in-CS groups' mission statements are often dominated by a few common words like "women", "computer", "science", "community", and "professional". However, no information on characteristic words for individual mission statement is available. Thus, this would be an excellent opportunity to use tf-idf as a statistic to find characteristic words for individual mission statement. Specifically, for this analysis, each school's mission statement is considered as a document, and the whole set of mission statements are the collection or corpus of documents.

The figure below shows some of the most important words, as measured by tf-idf.

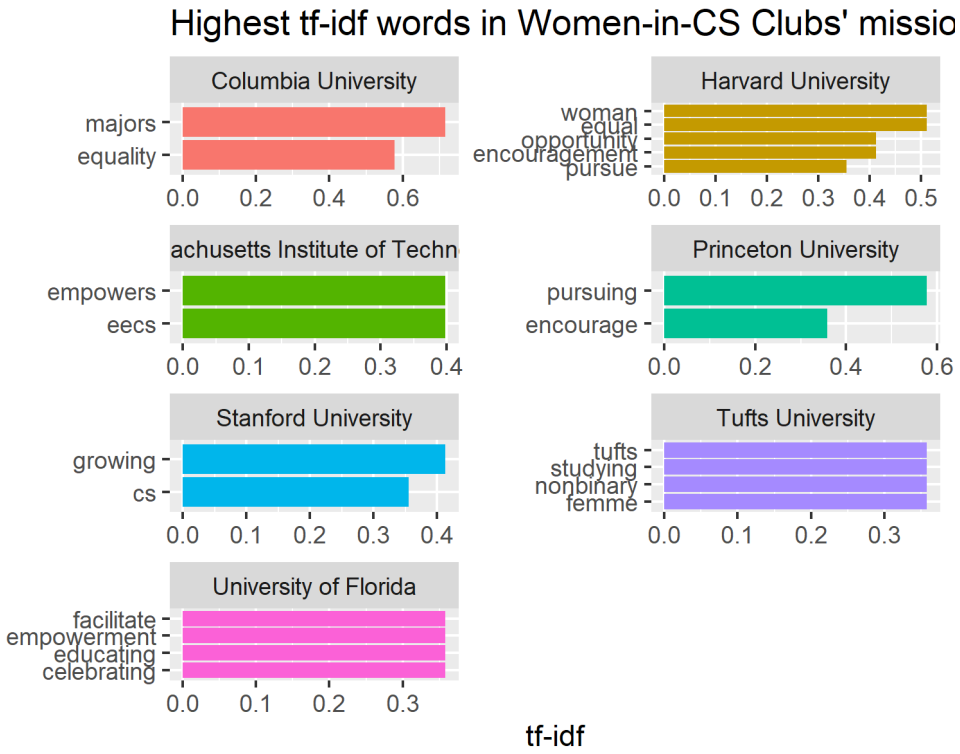


Figure 8: Highest ti-idf Words in Mission Statements

Compared to the most common words and pairwise counts, a few new words are trending to be common from tf-idf. For example, we see "equality" from Columbia University and "equal" from Harvard University, which suggests some of the clubs pay particular attention to ensuring women have equal rights in pursuing computer science. We also see "empower" from Massachusetts Institute of Technology and "empowerment" from University of Florida, which may then suggest empowering women being one central value or belief among some of the clubs.

Topic Modeling. Using tf-idf as a statistic has already given us insight into the content of Women-in-CS groups' mission statements, which I consider as a proxy to their

values and beliefs. But let's try topic modeling as an additional approach to the question of what the mission statements are about. Topic modeling is a method for unsupervised classification of documents, similar to clustering on numeric data, which finds natural groups among items despite the lack of prior hypotheses. Specifically, this approach models each document as a mixture of topics and each topic as a mixture of words, and a topic model "learns" to tell the difference between each Women-in-CS groups' website contents.

The figure below shows the top 10 terms of each topic from the topic modeling results.

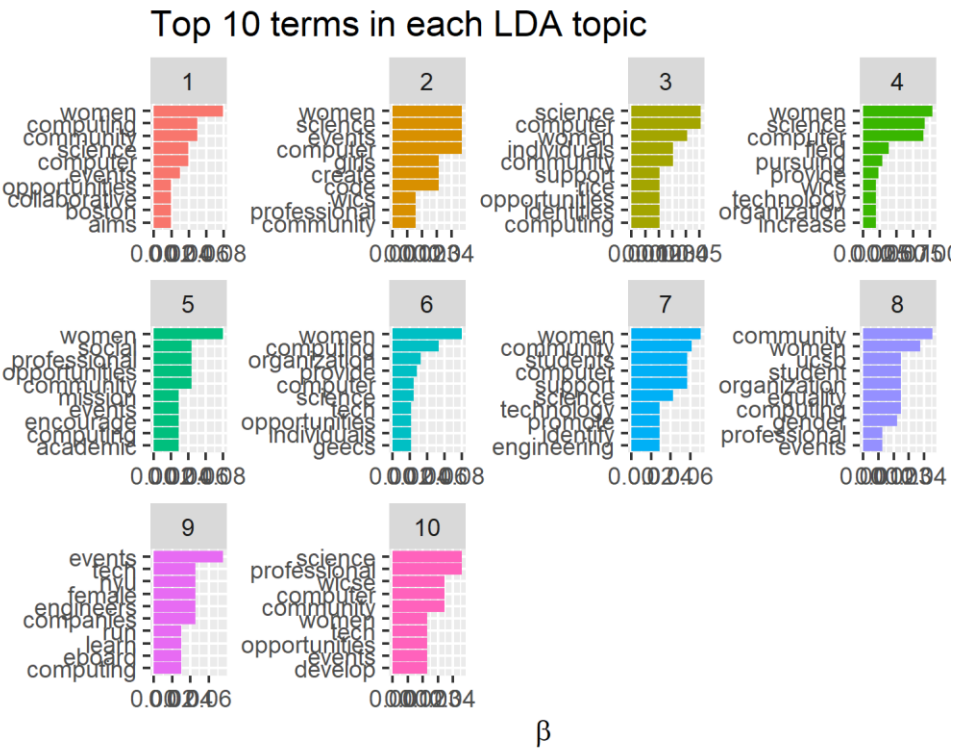


Figure 9: Top 10 Terms in Each LDA Topic from Topic Modeling

Besides words we have already seen in the previous analyses, such as “women”, “computer”, “science”, we also see words (or topics) like “community” and “identity”, which again suggests that Women-in-CS clubs care about building communities and forming identities for female students in computer science.

In sum, from a series of text analysis, “community”, “professional opportunity”, “equality”, “empowerment” seemed to be the salient ones in Women-in-CS clubs’ mission statements and therefore being core values and beliefs of such clubs. I will then use these as categories to guide the next step’s preliminary coding.

Values from the Preliminary Coding

As mentioned in the text analysis section, a few core values and beliefs have emerged from the mission statements. Here I redefine them as community, opportunity, equality/inclusion, and encouragement/support, and I now provide definitions and examples for each of these categories.

Community. Community in this context refers to whenever the clubs mention creating or fostering a community for female students in computer science and increasing their sense of belonging or sense of community in their mission statements.

Opportunity. Opportunity refers to mentioning providing opportunities or resources for women in computer science in the clubs’ mission statements so that female students become aware of their professional options by pursuing a computer science degree.

Equality/Inclusion. Equality/inclusion is used to categorize mentioning of seeking equal rights or equal access or making the campus more inclusive. It is also used to code mentioning of welcoming other gender minorities into the club.

Encouragement/Support. Encouragement/support is used to code whenever the clubs mention things like “encourage women to study CS” or “empower women in CS” or “support women pursuing CS”.

Programs/event Types from the Preliminary Coding

Using a similar approach to what I just presented for the values and missions, 8 types of programs/events were identified: Mentorship, Grace Hopper Celebration, Community Outreach, Corporate, Advocacy, Social, Technical, and Faculty. Here I illustrate what each of these programs/event types mean by providing definitions and examples.

Mentorship. Mentorship is a relationship in which a more experienced person (mentor) provides guidance on skill and professional development to a less experienced person (mentee). In the context of Women-in-CS groups, mentors are usually upperclassmen and mentees are usually underclassmen. Mentorship programs designed by Women-in-CS groups often allow mentor-mentee pairs to meet regularly to set academic and career goals, strengthen problem solving (coding) skills, and expand professional connections and networks.

Grace Hopper Celebration. Grace Hopper Celebration is the world’s largest conference gathering of women technologists. Women-in-CS groups that offer Grace

Hopper Celebration events not only provide scholarships for students to attend the conference, but also offer various pre-departure trainings (e.g., mock interviews, coding practices, networking tips) to help students better prepare for the conference.

Community Outreach. Community outreach events provide opportunities for college female CS majors to go into local high school or middle school and connect with school-age girls. Such events are not about just making connection, but also offering free workshops for girls and stir their interests in studying computer science. Women-in-CS members often view community outreach events as a chance to give back because many of them were exposed to computer science this way when they were in middle or high school, and such experiences were vital in their later decision to major in computer science.

Corporate. Corporate events are events in which alumni or representatives from tech companies come to universities to host information sessions, organize career panel discussions, or provide specific workshops. These events are often sponsored or co-hosted by the coming companies and can be with or without recruiting purposes. For example, Google offers imposter syndrome workshops to many Women-in-CS groups to help university women tackle this far too common phenomenon.

Advocacy. Advocacy events offer public support for a particular policy. In the context of Women-in-CS groups, advocacy events are often about supporting diversity and inclusion in STEM or supporting feminists. Examples of advocacy events include organizing students to attend March for Science or hosting events where allies are invited to express why they support women in tech.

Social. Social events are where Women-in-CS members get together to eat, chat, and learn as a community. Typical social events include welcome back events at the beginning of each semester, ice cream social or movie nights in the middle of the semester, and end of year parties. Social events are often fun and low-pressured, giving Women-in-CS members a safe space to be their true selves.

Technical. Technical events, by its name, focus on the technical aspect of computer science. Technical events can be in the form of tech talks offered by invited speakers, programming workshops focusing on specific topics/languages, study hours where people can discuss assignments, or problem-solving challenges such as hackathons. The goal of such technical events is often about computer science skill development.

Faculty. Although Women-in-CS groups are student-run organizations, some groups in fact do involve faculty participation, especially female faculty. Instead of formal mentoring or advising relationship that are common at the department level, involvement of faculty in Women-in-CS groups are often eat-and-learn sessions where female faculty members would come to have lunch or dinner with Women-in-CS members and share their experiences. Such events allow faculty and students to have a less formal but closer relationship, and students can often relate to faculty experiences because many of the faculty members have gone through the same struggles when they were at school.

Data Preparation for Network Analysis

In order to prepare data for network visualization, I derived adjacency matrix from my original data and converted the adjacency matrix to network/igraph objects that can be plotted.

Data Visualization and Explanation

This section consists of two parts: visualization and interpretation for missions and values, and visualization and interpretation for programs and events. I will not only present bar plots and network graphs to show what missions and programs are emphasized by Women-in-CS clubs, but also use centrality calculation to make sense of the details and the nuances within the presented networks. The visualizations and explanations together can then inform us the current status of Women-in-CS clubs in the country, as well as these clubs' core values and practices as inferred by their websites.

Visualization of Missions and Values

Bar Plot. The bar plot below shows that among the 4 types of values and beliefs identified from Women-in-CS clubs' mission statements, community is the most popular one, followed by encouragement/support, opportunity, and lastly equality/inclusion. Although we might think promoting equality and inclusion being critical for such groups, it is in fact less salient compared to other ones, at least based on their mission statements on the websites. It is also interesting to note that compared to public universities, private universities tend to value equality and inclusion more in their mission statements.

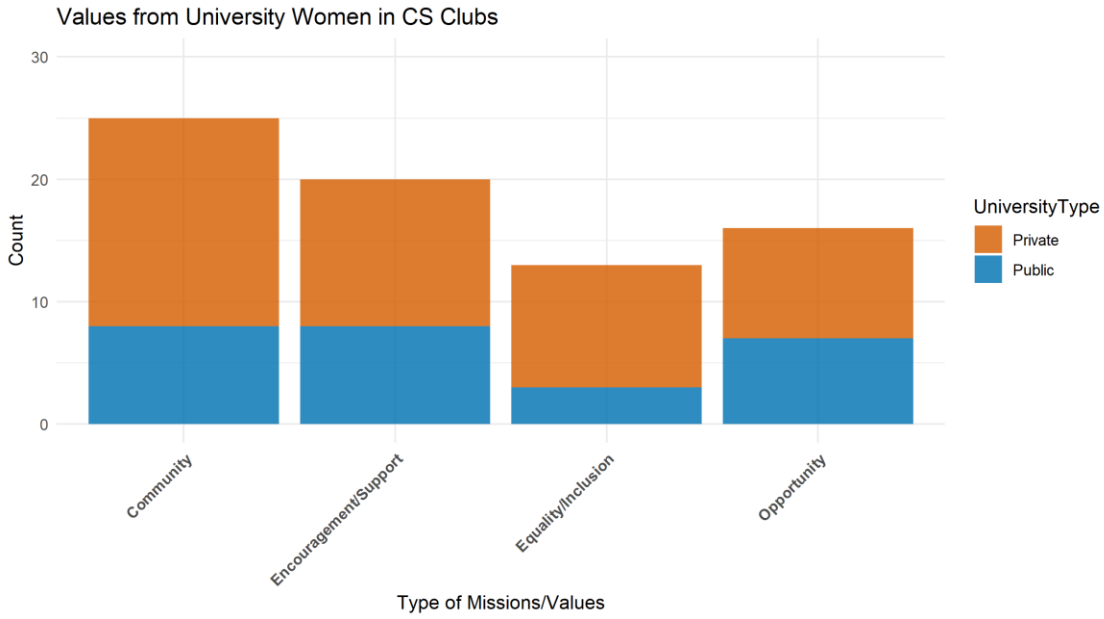


Figure 10: Values from Women-in-CS Clubs

Static Network Visualization. Here I construct two different networks for missions and values: a network of university Women-in-CS clubs and a network of missions stated by Women-in-CS clubs.

***Network of University Women-in-CS Clubs*.** Below is a network of university women-in-cs groups, with nodes being universities and edges being the connection between universities (connection defined by the number of shared values and beliefs - indicated by mission statements - between universities). University type is shown by both the color and the shape of the nodes. And the size of the nodes represents the number of values and beliefs stated by that school's women-in-cs group. The size of the edges shows how many shared values and beliefs are available between the connected nodes.

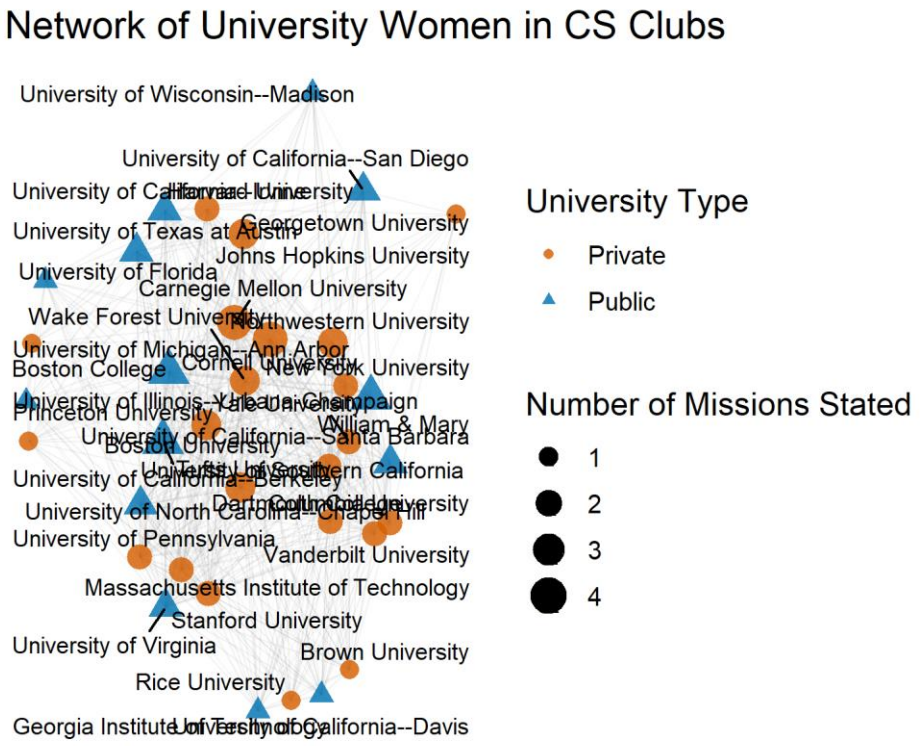


Figure 11: Network of Women-in-CS Clubs by Mission Statements

This figure reveals that some universities, especially the ones in the center, cover more values in their mission statements, whereas other universities, especially the ones on the "peripheral", mention fewer values in their mission statements. Such a finding suggests that the Women-in-CS groups in the center of the network might have gone through more iterations and tuning of their mission statements, and therefore have normalized their cultures in a way that is more structured and "tightened".

Network of Missions Stated by Women-in-CS Clubs. Below is a network of missions stated by women-in-cs groups, with nodes being types of missions or values and edges being the connection between missions (connection defined by co-occurrence of

missions or values in the same club). The size of the nodes represents the importance of this type of value or mission, with importance defined by number of clubs stating that mission or value. The size of the edges represents the number of co-occurrence of values or missions.

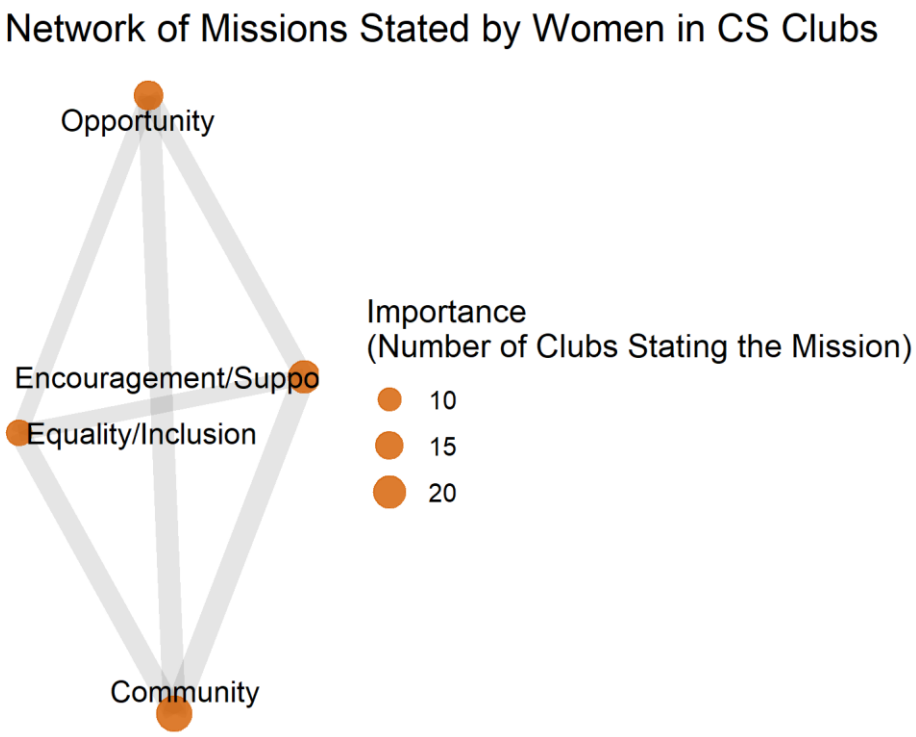


Figure 12: Network of Missions Stated by Women-in-CS Clubs

From the plot, we can see that community seems to be the most "central" value or belief among all the mission statements, suggesting community might be a core value in Women-in-CS clubs. However, the difference is not that large between community and other values, given that all four values or missions are shown to be quite important among all the clubs. The size of node for equality/inclusion is relatively small, indicating

that equality and inclusion has not been as “central” as other values or beliefs, and this result corresponds with what is shown on the bar plot previously. Moreover, both community and opportunity, and community and encouragement/support seem to have thickest edges, suggesting that they co-occur a lot in Women-in-CS clubs.

Calculating Centrality

Because the above networks contain a large number of nodes and edges and the representations have many overlap edges due to the size limit, it is hard to tell which school group or which type of mission statements/values is the most “central” one. Therefore, the next step is to calculate centrality, which can then allow for a more intuitive look at the most “central” school group or value. In network analysis, indicators of centrality assign numbers or rankings to nodes within a graph corresponding to their network position and provide answers to the question “what characterizes an important vertex”. The results of centrality calculation would then shed light on identifying the most influential university group in the country and the key values and beliefs they convey.

There are many available centrality measures that have been developed for network analysis. The calculation below only includes the “big four” measures (degree, betweenness, closeness, and eigenvector) available in the `igraph` package.

Degree Centrality. Degree centrality is the simplest centrality; it is defined as the number of links incident upon a node (i.e., the number of ties that a node has).

Eigenvector Centrality. Eigenvector centrality is a measure of the influence of a node in a network. It assigns relative scores to all nodes in the network based on the concept that connections to high-scoring nodes contribute more to the score of the node in question than equal connections to low-scoring nodes.

Closeness Centrality. Closeness centrality (or closeness) of a node is the average length of the shortest path between the node and all other nodes in the graph. Therefore, the more central a node is, the closer it is to all other nodes.

Betweenness Centrality. Betweenness centrality (or betweenness) is a centrality measure of a vertex within a graph that quantifies the number of times a node acts as a bridge along the shortest path between two other nodes. Vertices that have a high probability to occur on a randomly chosen shortest path between two randomly chosen vertices have a high betweenness.

Comparing Centrality Scores. In order to easily identify the most "central" node, I now save each of the above centralities as a vertex attribute and put them all together in one data frame.

I then constructed tables to display the top 5 university Women-in-CS groups by different measures of centrality and explain what each measure tells us. This way of organizing the results facilitates quick identification of Women-in-CS groups that currently have higher influence, which can then provide structural models for the design of these groups. Here, influence does not mean that the Women-in-CS groups exchange information with each other in reality. Rather, I would define influence here as something

close to the idea of “cultural centrality” or “cultural influence”—being central suggests their statements are more fine-tuned and their values are more comprehensive. Therefore, centrality calculations here highlight Women-in-CS groups’ shared connections and suggest directions for how these groups may start learning from each other if they want to make their groups better.

The table below displays the top 5 university Women-in-CS groups by its degree centrality. Degree centrality finds the very connected groups that are likely to hold most information or can quickly connect with the wider network. Therefore, the displayed table indicates that Women-in-CS groups from Carnegie Mellon University, Cornell University, Boston University, Tufts University, and University of California–Berkeley have most connections in the network and can quickly connect with the wider network.

Table 2: Top 5 Women-in-CS Clubs by Degree Centrality Based on Missions

	degree
Carnegie Mellon University	1.0000000
Cornell University	1.0000000
Boston University	0.9714286
Tufts University	0.9714286
University of California--Berkeley	0.9714286

The table below displays the top 5 university Women-in-CS groups by its eigenvector centrality. Groups with the highest eigenvector centrality suggest that these groups have the highest influence in the given network. Therefore, the displayed table indicates that Women-in-CS groups from Carnegie Mellon University, Cornell University, University of California–Berkeley, Boston University, and University of

Michigan–Ann Arbor have the highest influence in the network of values and missions, and that their missions tend to be the most “mature” among all the clubs at this point.

Table 3: Top 5 Women-in-CS Clubs by Eigenvector Centrality Based on Missions

	eigenvector
Cornell University	1.0000000
Carnegie Mellon University	1.0000000
Boston University	0.8409594
University of California--Berkeley	0.8409594
University of Michigan--Ann Arbor	0.8409594

The table below displays the top 5 university Women-in-CS groups by its closeness centrality. Groups with the highest closeness centrality suggest that these groups are best placed to influence the entire network most quickly. Therefore, the displayed table indicates that Women-in-CS groups from Brown University, Georgia Institute of Technology, Rice University, University of California–Davis, and Massachusetts Institute of Technology are approximately placed in the geometric center of the values/missions network and they are best placed to influence the values/missions network in terms of broadcasting information.

Table 4: Top 5 Women-in-CS Clubs by Closeness Centrality Based on Missions

	closeness
Brown University	0.02127660
Georgia Institute of Technology	0.02127660
Rice University	0.02127660

```
University of California--Davis       0.02127660
Massachusetts Institute of Technology 0.02040816
```

The table below displays the top 5 university Women-in-CS groups by its betweenness centrality. Groups with the highest betweenness centrality suggest that these groups are “bridges” between nodes in the given network. The results are actually similar to the analysis of closeness centrality, with an exception of Harvard University replacing Massachusetts Institute of Technology. The displayed table indicates that Women-in-CS groups from Brown University, Georgia Institute of Technology, Rice University, University of California–Davis, and Harvard University are on the periphery of network, but they might in fact affect the information flow around the system.

Table 5: Top 5 Women-in-CS Clubs by Betweenness Centrality Based on Missions

	betweenness
Brown University	13.20633
Georgia Institute of Technology	13.20633
Rice University	13.20633
University of California--Davis	13.20633
Harvard University	10.58480

Similar to what have been computed for the school network, same data frame and tables were constructed to display the values and missions network in descending order by different measures of centrality and explain what each measure tells us.

The table below displays the values/missions in descending order by degree centrality. Values/missions with the highest degree centrality suggest that these values/missions are popular among all the Women-in-CS groups. Therefore, the

displayed table indicates that all four values and missions are very popular among all the Women-in-CS groups, and they are of great importance in the design and planning of the Women-in-CS groups.

Table 6: Values in Descending Order by Degree Centrality

	degree
Community	1
Encouragement/Support	1
Equality/Inclusion	1
Opportunity	1

The table below displays the values/missions in descending order by eigenvector centrality. Values/missions with the highest eigenvector centrality suggest that these values/missions have the highest influence in the given network. Therefore, the displayed table indicates that community value has the highest influence in the network of values/missions, and that it is the "core" value in the design and planning of such Women-in-CS groups.

Table 7: Values in Descending Order by Eigenvector Centrality

	eigenvector
Community	1.0000000
Encouragement/Support	0.8766978
Opportunity	0.8476550
Equality/Inclusion	0.7319234

The table below displays the values/missions in descending order by closeness centrality. Values/missions with the highest closeness centrality suggest that it is best

placed to influence the entire network most quickly. Therefore, the displayed table indicates that the value of equality and inclusion is approximately placed in the geometric center of the values/missions network and it may be best placed to influence the values/missions network in terms of broadcasting information.

Table 8: Values in Descending Order by Closeness Centrality

	closeness
Equality/Inclusion	0.04761905
Opportunity	0.04000000
Encouragement/Support	0.03846154
Community	0.03125000

Because the values/missions network have all nodes connected to others, betweenness centrality for such a complete network is zero for every node. Therefore, it is meaningless to display the result, but it suggests that all these values and missions are important from the betweenness calculation.

Visualization of Programs and Events

Bar Plot. The bar plot below shows that there are 8 types of programs/events offered by the university Women-in-CS groups in the data set. Among these programs/events, social program/event is the most popular one, with all 40 groups having this type of program/event. Advocacy program/event is the least common type, with only 3 out of 40 schools having advocacy program/event. The plot also illustrates the number of different types of programs/events offered by either private universities or public universities.

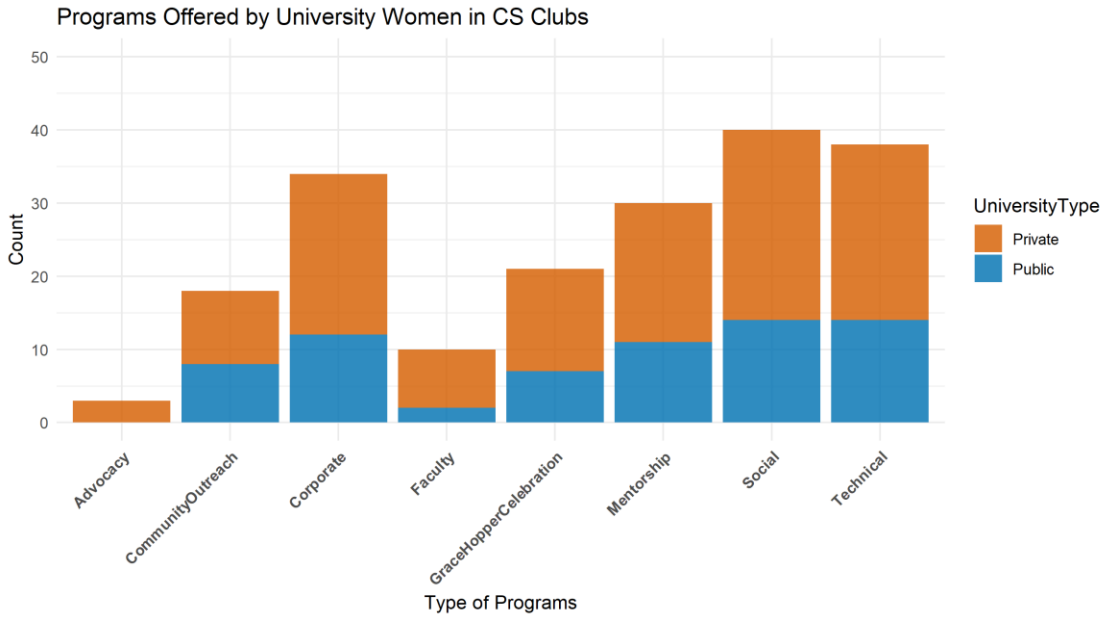


Figure 13: Programs Offered by Women-in-CS Clubs

Static Network Visualization. Here I construct two different networks: a network of university women-in-CS groups and a network of programs/events offered by women-in-CS groups.

Network of University Women-in-CS Groups. Below is a network of university Women-in-CS groups, with nodes being universities and edges being the connection between universities (connection defined by the number of shared programs between universities). University type is shown by both the color and the shape of the nodes. And the size of the nodes represents the number of programs offered by that school's Women-in-CS group. The size of the edges shows how many shared programs are available between the connected nodes.

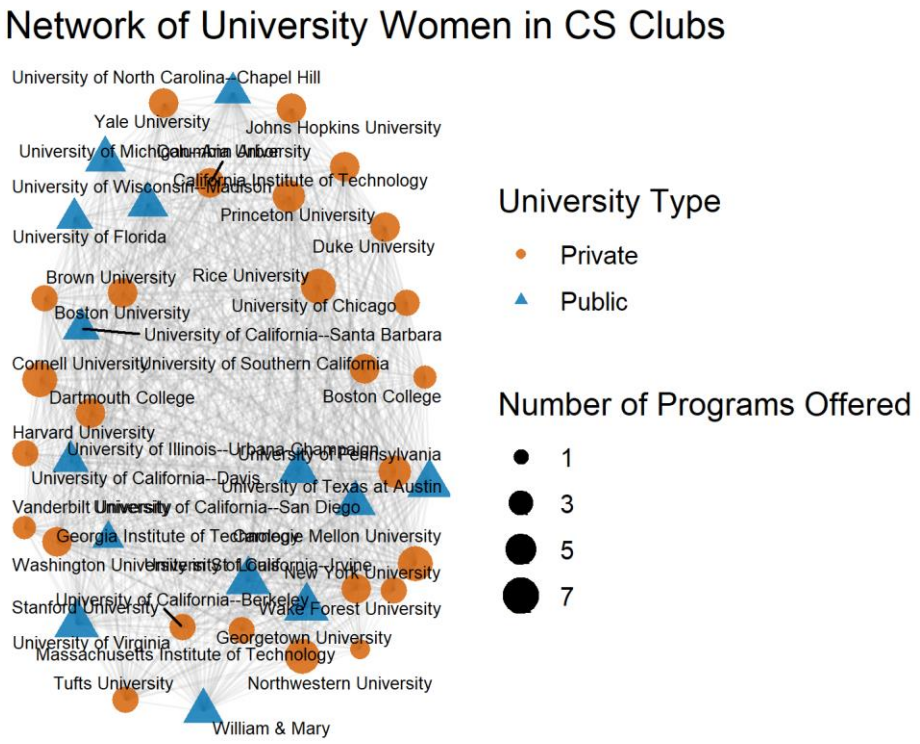


Figure 14: Network of Women-in-CS Clubs by Programs

Network of Programs/Events Offered by Women-in-CS Groups. Below is a network of programs/events offered by Women-in-CS groups, with nodes being types of programs and edges being the connection between programs (connection defined by co-occurrence of programs in the same club). The size of the nodes represents the importance of this type of program, with importance defined by number of clubs offering the program. The size of the edges represents the number of co-occurrence of programs.

From the plot, we can see that social events seem to be the most "central" program among all the programs, suggesting social events might be a core structure in Women-in-CS clubs. Also, social events, community outreach events, and mentorship

events have most and thickest edges, suggesting that they co-occur a lot in women in CS clubs. Advocacy program has the smallest size and fewest connections, suggesting it might be a peripheral program in the current structure of Women-in-CS clubs and not many schools have this type of program.

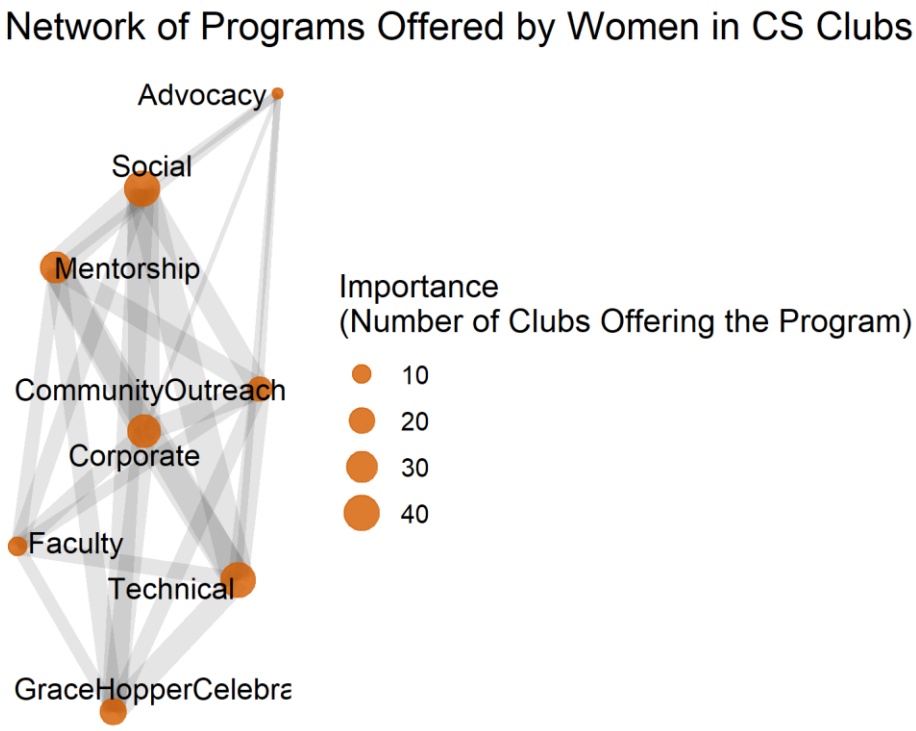


Figure 15: Network of Programs Offered by Women-in-CS Clubs

Calculating Centrality

Again, because the above networks contain a large number of nodes and edges, and the representations have many overlap edges due to the size limit, it is hard to tell which school group or which type of programs/events is the most "central" one. Therefore, centralities are calculated to allow for a more intuitive look at the most

"central" school group or program/event. The results of centrality calculation would then shed light on identifying the most influential university group in the country and the key infrastructures in the design and planning of university Women-in-CS groups.

Again, the calculation only includes the "big four" measures (degree, betweenness, closeness, and eigenvector) available in the `igraph` package. In order to easily identify the most "central" node, each of the above centralities was saved as a vertex attribute and then is put in one data frame.

I then constructed tables to display the top 5 university Women-in-CS groups by different measures of centrality and explain what each measure tells us. Because all the Women-in-CS groups in the examined data set have at least one shared program/event - social events, the degree centrality measure turns out to be 1 for all the groups and becomes meaningless.

The table below displays the top 5 university Women-in-CS groups by its eigenvector centrality. Groups with the highest eigenvector centrality suggest that these groups have the highest influence in the given network. Therefore, the displayed table indicates that Women-in-CS groups from Cornell University, Northwestern University, Rice University, Carnegie Mellon University, and University of California–Berkeley have the highest influence in the network of programs/events, and that they tend to be the most "mature" groups at this point.

Table 9: Top 5 Women-in-CS Clubs by Eigenvector Centrality Based on Programs

	eigenvector
Carnegie Mellon University	1.0000000
Cornell University	1.0000000
Rice University	1.0000000
Northwestern University	1.0000000
University of California--Irvine	0.9491947

The table below displays the top 5 university Women-in-CS groups by its closeness centrality. Groups with the highest closeness centrality suggest that these groups are best placed to influence the entire network most quickly. Therefore, the displayed table indicates that Women-in-CS groups from Georgetown University, Harvard University, Georgia Institute of Technology, Massachusetts Institute of Technology, and Boston College are approximately placed in the geometric center of the programs/events network and they are best placed to influence the programs/events network in terms of broadcasting information.

Table 10: Top 5 Women-in-CS Clubs by Closeness Centrality Based on Programs

	closeness
Georgetown University	0.013157895
Harvard University	0.011494253
Georgia Institute of Technology	0.010416667
Massachusetts Institute of Technology	0.009345794
Boston College	0.009174312

The table below displays the top 5 university Women-in-CS groups by its betweenness centrality. Groups with the highest betweenness centrality suggest that these

groups are “bridges” between nodes in the given network. The results are actually the same as the closeness centrality. The displayed table indicates that Women-in-CS groups from Georgetown University, Harvard University, Georgia Institute of Technology, Massachusetts Institute of Technology, and Boston College are on the periphery of network, but they might in fact affect the information flow around the system.

Table 11: Top 5 Women-in-CS Clubs by Betweenness Centrality Based on Programs

	betweenness
Georgetown University	272.2388889
Harvard University	136.1500000
Georgia Institute of Technology	29.1888889
Boston College	0.7222222
Vanderbilt University	0.7222222

Similar to what have been computed for the school network, same data frame and tables were constructed to display the programs/events in descending order by different measures of centrality and explain what each measure tells us.

The table below displays the programs/events in descending order by degree centrality. Programs/events with the highest degree centrality suggests that these programs/events are popular programs/events among all the Women-in-CS groups. Therefore, the displayed table indicates that community outreach events, corporate events, mentorship programs, social events, and technical events are all very popular among all the women-in-CS groups and they are of great importance in the design and planning of the Women-in-CS groups.

Table 12: Programs in Descending Order by Degree Centrality

	degree
CommunityOutreach	1.0000000
Corporate	1.0000000
Mentorship	1.0000000
Social	1.0000000
Technical	1.0000000
Faculty	0.8571429
GraceHopperCelebration	0.8571429
Advocacy	0.7142857

The table below displays the programs/events in descending order by eigenvector centrality. Programs/events with the highest eigenvector centrality suggest that these programs/events have the highest influence in the given network. Therefore, the displayed table indicates that social events has the highest influence in the network of programs/events, and that it is the most "important" structure in the design and planning of such Women-in-CS groups. Technical events and corporate events also seem to be critical in the structure of Women-in-CS groups. Advocacy events, probably because very few groups hold such events, has the lowest eigenvector centrality and therefore is the least influential component in Women-in-CS groups, at least up to this point.

Table 13: Programs in Descending Order by Eigenvector Centrality

	eigenvector
Social	1.00000000
Technical	0.97181639
Corporate	0.92655330

```
Mentorship              0.84915604
GraceHopperCelebration  0.64674821
CommunityOutreach       0.57389809
Faculty                 0.35445078
Advocacy                0.07866396
```

The table below displays the programs/events in descending order by closeness centrality. Program/event with the highest closeness centrality suggest that it is best placed to influence the entire network most quickly. Therefore, the displayed table indicates that advocacy events is approximately placed in the geometric center of the programs/events network and it may be best placed to influence the programs/events network in terms of broadcasting information.

Table 14: Programs in Descending Order by Closeness Centrality

```
                        closeness
Advocacy               0.03225806
CommunityOutreach      0.02857143
Corporate              0.02631579
Technical              0.02325581
Mentorship             0.02173913
Social                 0.02083333
Faculty                0.01724138
GraceHopperCelebration 0.01162791
```

The table below displays the programs/events in descending order by betweenness centrality. Program/event with the highest betweenness centrality suggest that it is the "bridge" between nodes in the given network. The results are similar to the closeness

centrality, with advocacy events again has the highest betweenness centrality. The displayed table indicates that advocacy events is on the periphery of network, but it might in fact affect the information flow around the system.

Table 15: Programs in Descending Order by Betweenness Centrality

	betweenness
Advocacy	14.5
CommunityOutreach	6.5
Faculty	1.0
Corporate	0.0
GraceHopperCelebration	0.0
Mentorship	0.0
Social	0.0
Technical	0.0

Discussion

Moving from simple word frequency to co-occurrence and finally to network visualizations, the analyses above illustrate what missions and programs are highlighted and emphasized by the Women-in-CS clubs, which reflect values and practices respectively. In particular, community turns out to be the core value and social events turn out to be the most popular practice. With such results, I want to further ask: how do values and practices relate to each other?

In fact, it is not that hard to reason the relationship between the value of community and the prevalence of social events. Let’s look back at how community and social events were operationalized in the previous analyses: community refers to

mentioning of creating or fostering a community for female students in computer science, and social events are where Women-in-CS members get together to eat, chat, and learn as a community. Obviously, the idea of community is deeply embedded in social events, and that probably explains why community is the most core value and social is the most popular type of practice — they do align with each other well.

Besides the alignment of the most core value and the most popular type of event, we can also speculate some alignment between the relatively least popular ones: equality/inclusion from the value, and advocacy from the practice. Again, if we refer back to how these categories were operationalized, we can see that advocacy events call for public support on diversity, equity, and inclusion. Thus, the value of equality/inclusion is deeply rooted in the design of advocacy events, which helps explain why both are shown to be less "central" than the other ones.

Another approach to examine the relationship between values and practices is by cross-referencing centrality calculations. For example, looking at eigenvector centrality, Carnegie Mellon University, Cornell University, University of California–Berkeley, Boston University, and University of Michigan–Ann Arbor are the top 5 for missions and values, Cornell University, Northwestern University, Rice University, Carnegie Mellon University, and University of California–Berkeley are the top 5 for programs and events. Among these, Carnegie Mellon University, Cornell University, and University of California-Berkeley are shown on both lists, suggesting that they have the highest impact and tend to be the most "mature" groups from both values and practices perspectives. Again, influence here reflects the idea of "cultural centrality" and suggests clubs with

higher influence have probably tuned statements more finely. From a tight-loose culture perspective, such high influence could also be interpreted as more structures or "tighter" culture (Gelfand, 2018). Similarly, looking at closeness centrality, Brown University, Georgia Institute of Technology, Rice University, University of California–Davis, and Massachusetts Institute of Technology are the top 5 for missions and values, Georgetown University, Harvard University, Georgia Institute of Technology, Massachusetts Institute of Technology, and Boston College are the top 5 for programs and events. Again, Georgia Institute of Technology and Massachusetts Institute of Technology are on both lists, indicating that they are best placed to influence the information broadcasting either from both values and practices perspectives. Of course, there is no way that the values and practices networks are perfectly aligned, but at least we start to see some matches across both networks. Such results not only tell us what Women-in-CS groups have higher impact now and might be a good "model" when designing such organizations, but also shed light on the possible underlying mechanism in terms of why they are more successful — having their values and practices aligned so that their practices are intentionally designed to address and reflect their values and beliefs.

There is one more research question I want to answer from this study: do the values and the practices identified by network analysis address the challenges of women in computer science identified by previous research? And if so, how?

The wicked problem of gender inequality in computer science has been around for decades. Lagesen (2011) summarized this problem and the attempted remedies into deficits in women and deficits in computer science. The first focuses on women's lesser

knowledge or experience of computers, and then the related lack of skills or interest in the field (Celik & Ipcioglu, 2007; He & Freeman, 2009). The second focuses on the field of computer science itself being "masculine" and therefore unattractive and structurally unwelcoming to women (Martin, 2001). Such "deficit models" may not be correct, but they do reflect the challenges in increasing the number of female computer scientists.

Now let's rethink Women-in-CS groups: do these groups address either or both of the deficits? Although we, or Women-in-CS groups themselves, might not agree with these "deficit models" characterization, their values and practices can in fact be categorized into remedies that address both deficits. On the one hand, if we look at values and beliefs first, "community", "equality/inclusion", and "encouragement/support" from their mission statements are all somewhat related to deficits in computer science, with the hope to change the field of computer science to be more inclusive and supportive for the female community, rather than being a masculine field just for men. "Opportunity" from their mission statements speaks to deficits in women, with the hope to provide females with more resources, skills, and experiences so that they can succeed. On the other hand, looking at programs and practices, "community outreach", "advocacy", "social", and "faculty" events are all about deficits in computer science. These programs and practices are all designed to make the field of computer science more attractive and welcoming for women, not only for college students themselves but also for girls at younger ages in middle school or high school. "Mentorship", "Grace Hopper Celebration", "corporate", and "technical" events are designed to help women build skills at various capacity, which is related to the viewpoint of deficits in women.

Limitation

This study only looks at the Women-in-CS groups among the top 50 universities in the U.S.; therefore, the sample is limited and not very representative. However, because no research to our knowledge has looked at these groups in detail, the sample I selected serves the need to provide an initial understanding of these groups, especially with both public and private universities in the selected sample. In addition, considering the fact that computer science is a fast-developing field, examining elite universities where there are richer resources for the development of the field of computer science may give us hints on how things can succeed or break in different contexts (e.g., community colleges).

Conclusion

In summary, this study mainly uses a network analysis approach to explore the current status of undergraduate Women-in-CS groups in the United States. The network visualizations rendered some interesting results in terms of the design of Women-in-CS groups, with particular emphases on the value of community and the importance of social events. Moreover, centrality calculations allow us to identify a few "model" clubs in the country, which might offer schools who are considering establishing such groups a good starting point. Furthermore, alignments between values and practices are also identified through the analyses, along with some possible explanations. In addition, these Women-in-CS groups' mission statements and programs directly speak to the challenges of gender inequality in computer science identified by previous research, which might

provide a reason for the need of such groups and potentially the mechanism of why such groups can help increase the number of women in computer science.

Nevertheless, as the first study in my dissertation, this study does not directly speak to how students engage in such groups and why these groups are successful from an organizational change perspective. Those questions will be answered in the next research—an intensive ethnographic study of one Women-in-CS group.

Chapter 5: Applying A Multi-Faceted Framework for Understanding Change in One Particular Women-in-Computing (WiC) Club

As introduced in Chapter 2, there are three theories of change that are particularly relevant in the context of Women-in-CS Clubs: social cognition, cultural, and institutional. These three theories of change provide a foundation for understanding why Women-in-CS Clubs at universities could be effective in broadening females' participation in computer science, especially with regards to their missions and values, which was discussed in detail in Chapter 4. However, missions and events from Women-in-CS clubs' websites only offer limited information, and without further research, we cannot know whether the stated values and missions of the clubs actually reflect or influence their activities. After all, many of the mission statements are aspirational, and the actual practices might turn out to be quite different. Moreover, the three theories of change mentioned above provide a theoretical lens to look at the Women-in-CS clubs, but themselves, alone, are not sufficient enough for a deeper understanding of change that would allow us to provide a more detailed, nuanced, and relevant analysis of the causes and processes of change.

Therefore, in this chapter, I report on a case study of one Women-in-Computing (WiC) club at a private university in the Midwest. I aimed to answer the following three research questions from this case study: How do students engage in Women-in-CS groups? What are the impacts of such groups, on both individual female computer science students and on computer science department or the field of computer science? How did changes occur?

Specifically, the first question about engagement is a follow-up on the network analysis study in Chapter 4, and I used results from that study to guide my investigation for the current chapter and investigated the relation between website content and actual club activities. The remaining questions focus more on the process of change, and I applied a multi-faceted framework for understanding change in this particular WiC that I conducted this research on. Such an approach enabled me to better interpret changes brought by WiC and provide an analytical tool that can be used broadly to examine Women-in-CS clubs in more detail. My goal is both to use this framework to analyze and articulate changes in WiC, and also to use the framework to guide the derivation of design principles. In the next section, I discuss this multi-faceted framework for understanding change that I relied on in my exploration to examine change driven by WiC.

Framework

In her book *How Colleges Change: Understanding, Leading, and Enacting Change*, Adrianna Kezar (2014) invited readers to think differently about organizational change and provided a multi-faceted framework for understanding change. Through research on how to successfully create change, Kezar (2014) reviewed elements of this change framework that were critical in understanding the change process, including but not limited to agency of change, resistance and obstacles during change, and types of change. By connecting these various features back to the theories of change (discussed in Chapter 2 of this dissertation), Kezar (2014) provided rationale for why they are important to facilitate change and move toward action. Therefore, in the context of

studying WiC's practices and its impacts, this framework can be extremely useful in articulating the process of change driven by WiC, by decomposing change process into these elements and features. I now elaborate on elements that are particularly relevant and important on my analytical framework for the case study of WiC.

Levels of Change

As discussed in Chapter 2, WiC is the group level that sits in between the individual level female computer science students and the organizational level computer science department. Based on the findings from Chapter 4, many Women-in-CS groups' current values and practices focus on female students' sense of belonging and sense of community, which are changes at the individual level. Changes at the institutional level also cannot be overlooked. Therefore, when assessing WiC's impacts, both individual and organizational level should be examined.

Leadership and Agency of Change

Leaders who act as change agents are perhaps the most important individuals for change, without whom there would be little change. Specifically, there are leaders who are top-down and in positions of authority versus those who are bottom-up and more grassroots oriented. I view WiC executive board leaders as both top-down and bottom-up leaders. To general WiC members, WiC executive board leaders are top-down leaders because they are in positions of power and they create strategic plans, refine mission statements, and build structures. At the same time, to the Computer Science Department, the School of Engineering, or even the entire institution, WiC executive board leaders are bottom-up leaders who leverage student relationships in seeking allies and negotiating

interests. This perspective is consistent with the “bridge” function that I discussed in Chapter 2: WiC as a group act as a bridge that connects individual level female computer science students and organizational level computer science department. The fact that WiC is located between two levels and in the middle of the hierarchy allows WiC executive board leaders to act as change agents who are both top-down and bottom-up.

According to Kezar (2014), strategies and approaches relating to top-down leadership include the following: 1) establishing core values, vision or mission; 2) using planning mechanisms; 3) using resources and funding; 4) motivating people through incentives or rewards; 5) restructuring or creating support structures; and 6) hiring and training of employees. Kezar (2014) also suggested that the bottom-up strategies for creating change and exerting agency include the following: 1) intellectual opportunities; 2) professional development; 3) leveraging curricula and using classrooms as forums; 4) joining and utilizing existing networks; 5) working with students; 6) hiring like-minded people; 7) gathering data; 8) garnering resources; and 9) partnering with influential external stakeholders.

In addition to the top-down and bottom-up dichotomy that focuses more on individuals as change agents, Kezar (2014) also discussed leadership as a shared or collective process. This is actually another excellent approach to look at WiC executive board leaders. On a WiC executive board, there are usually 8-10 executive board members, holding different positions such as internal president, external president, programming chair, outreach chair, public relation chair, historian, treasurer, etc. Although WiC executive board leaders each hold different positions on the executive

board, often the times leadership is exercised not only by individuals but also a collective effort.

Perhaps not every single strategy identified by Kezar (2014) is relevant in the context of WiC, but at least the strategies reviewed in the literature can provide a guiding analytical framework for me to look at change in WiC. These are discussed in the results section.

Resistance and Obstacles

Resistance and other obstacles are inevitable in any effort to engender organizational change. Resistance and obstacles may be internal or external, and they are often connected to theories of change. I examined resistance and obstacles from the three theoretical perspectives on organizational change mentioned above: social cognition, cultural, and institutional.

From a social cognition perspective, mental models that individuals hold can be a source of resistance and obstacles that prevent people from engaging with change because they might fail to reconcile the new ideas with their old mental models (Johnson-Laird, 1980; Johnson-Laird, 2013). To overcome such obstacles, it is necessary to help people who are involved in the change process to understand that change is being implemented. From a cultural change theory perspective, obstacles to change are about values and beliefs associated with change. When those values and beliefs violate existing cultural norms, people may find it hard to understand and have the tendency to resist change (Dawson, 1994; Kezar, 2001). From an institutional change perspective, changes within organizations that have strong institutional norms will almost always be resisted.

Such obstacles and resistance can be very common especially when different stakeholders involved in change have contradictory stances.

A closer look at resistance and obstacles that WiC encounters in its change initiatives and how they overcome such resistance and obstacles can provide more nuances for articulating changes in this setting and can provide insights for thinking about changes in similar contexts from a design perspective. Here, I used this multi-faceted framework for understanding change to closely examine the change process through levels of change, leadership and agency, and resistance and obstacles. My aim was to use this lens to answer the following research questions: What are the impacts of such groups, on both individual female computer science students and on Computer Science department or the field of computer science? What factors led to these changes?

My hypothesis was that WiC helps broadening participation of women in computing because various WiC practices directly address the challenges in literature, both at the individual level and at the organizational level. Also, I anticipated to see that WiC executive board leaders use different strategies to overcome resistance and obstacles and to engender changes.

Method

Participants

The participants in this study were members of the Women in Computing (WiC) club at a private university in the Midwest. Participants were recruited at WiC events and through the WiC listserv. Besides general WiC members, particular attention was paid to

WiC junior board members and WiC executive board leaders, who hold leadership positions and are in charge of planning and executing WiC events. This was because WiC execs are not only active members of WiC but also leaders who make organizational level decisions to achieve WiC's goals and reflect WiC's values.

Data Collection

Participant Observation with Field Notes and Video Recordings. I engaged in participant observation of WiC events during two consecutive academic years (2018-2019 and 2019-2020). Observing for two years allowed me to see changes and the development of leaders more closely. Events that were observed included Tech Talks (technical talks given by members or invited speakers), Hacknight (spaces for students to work on CS work collaboratively), Mentoring Programs (paring juniors and seniors with freshmen and sophomores), Faculty Lunches (quarterly conversation with female faculty), and Executive Meetings (weekly meetings for executive board members). I also attended the Grace Hopper Celebration (GHC) in October 2019 (Orlando, FL), to observe and participate in the physical and social spaces that WiC members were exposed to. The Grace Hopper Celebration (GHC) focuses specifically on women in computing and technology and is the largest gathering of women technologists in the world. The celebration provides networking, mentoring, and professional development for its attendees. Presenters at GHC are leaders in their respective fields, representing industry, academia and government. Therefore, GHC provided many opportunities to examine the impact of experiential learning on both individual's sense of belonging and on organizational culture and climate. I stayed with WiC members throughout the whole

conference and attended various events to collect audio recordings and field notes during GHC to capture WiC members' real-time experiences and reflections.

The use of the participant observation method allowed me to become deeply familiar with the practices and the WiC I was investigating, at a fine-grained level. The method of participant observation could potentially capture the essential details of everyday, situated activities that would always be missing from interview. The observations focused on the various practices WiC members perform during the events and how they addressed the previously identified causes and challenges of women in computer science, either through literature or through my first study of network analysis.

I took field notes of my observations in order to document moments of interactions. I also video recorded all the Executive Board Meetings and some selected events. After each recording, I immediately reviewed and developed time-indexed content logs of the video. Similar to field notes, content logs work to outline main activities and interactions that take place during the events, while also attending to moments relevant to my research foci.

Individual Interviews. I conducted one-on-one open-ended interviews of WiC members, to examine their experiences in WiC and how these experiences led to better individual learning outcomes and transformed community culture. Participants in the interviews were WiC executive board leaders. The interview questions were designed to center on WiC members' experiences in the community, both as general WiC members and as WiC executive board leaders after they became one. The full interview protocol is in Appendix A. For example, I asked WiC executive board leaders to think about their

very first impression of WiC, how they encountered WiC, when they joined WiC, and why they joined WiC. I also asked them if they have ever sought out help from others in WiC; and if so, why they did so or if not, what prevented them from doing so. I also invited WiC members to reflect on their sense of belonging in the field of computer science, what part of WiC worked in increasing their sense of belonging, and what can be done to improve. Moreover, I crafted additional questions on leadership and community culture. For example, I asked WiC executive board leaders why they decided to become a leader and what goals they had for WiC. I asked questions about what decisions they made to develop the community culture, how they decided those, and the changes they have seen over the years with respect to women's representation in the field of computer science. I also asked WiC executive board leaders to describe the challenges and obstacles they encountered in terms of increasing women's representation in computer science, as well as what support and help they received from the department and the school as they fought for the diversity. All the interviews were audio recorded and documented in field notes.

Reflection Forms. Reflection forms were designed for WiC executive board leaders in particular and were created to investigate WiC leaders' thoughts, reactions, or understanding of the day's executive meeting. I asked WiC executive board leaders to complete a reflection form during the last few minutes of every executive meeting to understand what their major take-aways are from the meeting, as well as their reflection on making organizational decisions as leaders. Information gathered from reflection forms provided formative data that helps in evoking key moments in meetings that might

not be recalled by WiC executive board leaders during the individual interview, as well as showing WiC leaders' trajectories throughout the academic year. Appendix B is the reflection form.

Relevant Artifacts. Artifacts from WiC such as photos, check-in and feedback forms, and executive board meeting minutes, etc, were also collected for in-depth analysis. These artifacts allowed me to see the programming of the events, how learning experiences for WiC members were designed and constructed, how WiC members engaged with the events, and if and how WiC members' sense of belonging in CS and their identity as female computer scientists changed over time.

Survey. Lastly, a survey was sent out to WiC listserv periodically throughout the academic years to assess changes in WiC members' sense of belonging in computer science. The survey was adapted from Walton et al.'s (2015) Sense of Social and Academic Fit (10 items, in STEM), and the full survey is in Appendix C. Specifically, the survey was distributed via the online survey platform Qualtrics in April 2019, September 2019, and January 2020, with 34, 17, and 9 responses from each distribution. Unfortunately, only 2 people completed the survey all three times, which made it impossible to examine the trends of change in sense of belonging. Therefore, the survey was then excluded from data analysis.

Data Analysis

Observational and interview data collected from this study was coded and analyzed qualitatively. I began by identifying salient themes, and then focused coding was used to closely examine relationships between themes and identify patterns of

relationships. I used a deductive, top-down analysis method driven by the theoretical perspectives I have identified earlier through a review of existing literature, as well as my research questions and my results from the first study (network analysis). Specifically, the approach I took was first developing taxonomy categories from findings from my Study 1 in Chapter 4, and the literature on college reform and organizational change literature, as illustrated previously in the framework section. Then a thematic analysis (Braun & Clarke, 2006) was used to search for evidence from WiC members' practices and language that fit with the pre-defined taxonomy categories. Evidence that I considered in coding included both the actions and movements enacted by the students during the events and the conversations that WiC members had during the events and from the interviews with me.

For the taxonomy categories that guided my analysis, several components of organizational change, including levels of change, leadership and agency, resistance and obstacles, were examined to understand changes driven by WiC. The table below illustrates the examined categories along with their definition in the context.

Table 16: Coding Categories and Definitions

Parameter	Code	Definition in the context
Levels of change	Change at the individual level	Changes related to individual students' sense of belonging.
	Change at the organizational level	Changes related to departmental culture, number of female students or faculty in the Computer Science Department.

Leadership and Agency	Establishing core values, vision or mission	Leaders have a clear direction for what a WiC is and what a WiC should be.
	Using planning mechanisms	Leaders have implementation plans and distributed roles and responsibilities.
	Using resources and funding	Leaders raise funds and allocate resources effectively for WiC.
	Motivating people through incentives or rewards	Leaders provide incentives for people to come to WiC events.
	Restructuring or creating support structures	Leaders restructure positions on the WiC executive board.
	Hiring and training of employees	Leaders hire and train underclassmen to take over WiC after they graduate.
	Intellectual opportunities	Leaders plan WiC events that foster learning for community members.
	Professional development	Leaders plan and host professional development workshops for WiC participants.
	Leveraging curricula and using classrooms as forums	Leaders use classroom resources to advertise WiC events.
	Joining and utilizing existing networks	Leaders collaborate with other student groups on campus who have larger networks.

	Working with students	Leaders design and organize events for students in WiC.
	Hiring like-minded people	Leaders hire like-minded people first on the junior board and then on the senior executive board.
	Gathering data	Leaders collect data on WiC members' participation and feedback.
	Garnering resources	Leaders garnering resources, such as financial support, to mobilize WiC members.
	Partnering with influential external stakeholders	Leaders partner with alumni in the industry to host mentoring and other events for WiC members.
Resistance and obstacles	Social cognition obstacles	Obstacles related to individuals' old mental model not updated along with new changes, such as students' feeling of incompetence.
	Cultural obstacles	Obstacles related to the culture of computer science, such as male-dominated.
	Institutional obstacles	Obstacles related to contradictory institutional norms on diversity and inclusion.

Additional evidence, such as reflection forms and artifacts, was used to triangulate results from participant observation and individual interviews.

Results

Research Question 1: How Do Students Engage in WiC?

The findings of this study align well with those of the earlier and more general network analysis. My observations and interviews revealed that the WiC's practices do

align with missions and values on the website quite well. Informal conversations with WiC general members during WiC events, and one-on-one interviews with WiC executive board leaders, uncovered students' rationales for joining WiC and attending various WiC events. Here I present evidence in support of students' engagement and involvement in various practices, and how such practices match with their stated missions and values on the website.

WiC "Is an Identity. There Is No Membership". Throughout the two academic years that I observed WiC events, I noticed that sometimes men attended the events. In addition, by looking at check-in and feedback forms created and distributed by WiC executive board, I noticed that there were attendees who self-identified as non-CS majors in almost all of the WiC events. Because WiC stands for Women in Computing, ostensibly these people seem not to fit the definition or purpose of WiC this definition. Then, why did they come to WiC events?

Former president of WiC provided an answer:

> *"You're in WiC if you are a WiC, like if you're computing, if you want to support. We keep saying it's an identity. There is no membership. You don't have to come to every event… It's an identity. It's a community…"*

For WiC, there is no membership—people don't need to submit an application or pay dues to attend WiC events. There is no boundary in terms of who can be a WiC or who can come to WiC events. In 2018, the executive board did introduce a point system to determine who would be eligible for Grace Hopper applications in 2018. Students

accumulated points for attending meetings or other events, and the number of points in part determined who could be funded to attend the Grace Hopper Celebration. However, the club soon abandoned the point system, as it was not well-received by either leaders or other attendees. The WiC president who decided to discontinue the point system provided the reasoning for abandoning it:

> *"If we only want people who can come to our events, I feel like I'm excluding a very large population of people who could really benefit from going to Grace Hopper. And there's a lot of things that come to play. Like, sometimes people are really busy, they can't come to our events. I had someone messaged me last year who was like, 'I'm so sorry, I don't go to WiC events. I spent a lot of time tutoring.' I'm like if you're tutoring other girls and that's even better than coming to our events."*

Active participation in WiC is not measured or defined by how frequently people come to WiC events. Rather, it can be inferred from what a student does to support WiC.

Likewise, students who were not majoring in computer science were welcomed to be in WiC if they were active in computing. In fact, 2 of the 9 members of the 2019 executive board were not computer science majors; at the time I interviewed them, one was a senior who used to be a computer science major but then switched to cognitive science, and the other was a freshman studying industrial engineering. The cognitive science major remained active in WiC even two years after leaving the computer science major. I asked why she wanted to remain active and serve on the executive board; she stated:

> *"I definitely felt a little out of place. But I guess I just really wanted to make sure that people had the support that I didn't really feel like I had… I kind of wanted to give the impression that anyone is welcome to join WiC. Even if you're not necessarily CS, like anyone who's interested in it or just wants to be part of the community… I just wanted to be in the background, making it better because I do feel like some parts of WiC were like a little bit inaccessible to people who weren't CS majors…"*

If we traced even further back to whether WiC executive board leaders started with a computer science major, five out of nine did not, including one of the two presidents of the 2018 executive board who was a senior at the time I interviewed her, two juniors who later became the presidents of the 2019 executive board, and another senior and a freshman. Their majors did not define whether they were WiC, and they started going to WiC events even before they officially became computer science majors.

Therefore, WiC is a community that welcomes people who are interested in computing or who just want to be part of the community. And WiC executive board leaders want to make it more accessible and inclusive.

Another WiC participant also shared her similar view on how she viewed WiC as a community:

> *"Once I started going regularly (to WiC events), I think I just felt comfortable in that community. Even if I didn't really know everyone there, I just felt like I belonged there, kind of."*

Such a sense of belonging or a sense of community naturally grew as people participated in WiC events. Just like what the former president said, *"It's an identity. It's a community."* Such an identity is not defined by students' majors, and the community of WiC is always there and always welcomes people.

From an event-planning perspective, there are WiC events that even intentionally target people who are just interested in computer science but are not necessarily in the major, or people who just want to support the community. For example, WiC hosted a Break Into CS Bootcamp in 2018, and this event is now held annually because participants find it very helpful. The Break Into CS Bootcamp targets freshmen in computer science major or freshmen and sophomores who are thinking about pursuing computer science. There are stations set up at which attendees can discuss a 4-year course plan for the computer science major, as well as on-campus resources, research labs, non-traditional paths for computer science students, etc.

During my observation and through some casual conversations, I learned that some students at the Break Into CS Bootcamp were a little conflicted about being CS majors, and they enjoyed the non-traditional paths station very much because they learned that there were other options besides coding that were open to them in the field of computer science.

The WiC executive board leader who started the idea of Break Into CS Bootcamp shared why she wanted to host this event:

> *"You know how some people are like really at CS, they had projects, clubs, all of them. There are others who are CS majors, but they have interest in many other things. I want to make sure that they also feel included in WiC and that WiC is not just for people who love CS."*

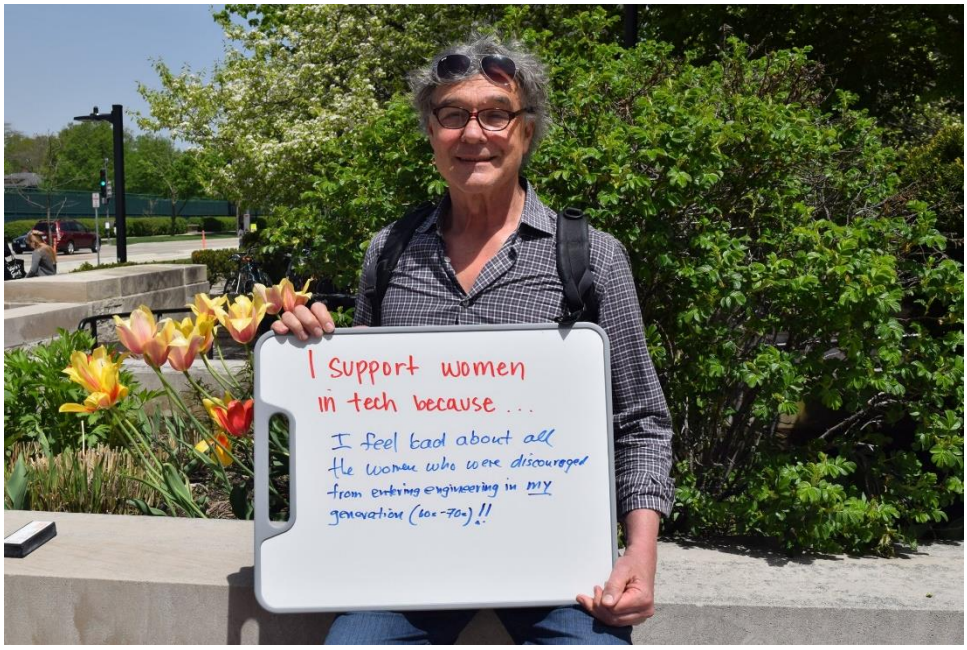
Moreover, even male students found Break Into CS Bootcamp very informative for them because they also had a lot of questions but they did not know where to go; they did not have a similar community or platform that provided such useful information.

Another annual event that targets broader audience is the Whiteboard Campaign, in which WiC members stand in front of the school of engineering building and ask for people to write on a whiteboard their reasons for supporting women in STEM. This event is no longer limited to women in computer science but is open to anyone who wants to support women in STEM in general. Figures below are some photos taken at the Whiteboard Campaign.

Table 17: Student Stating Why They Support Diversity in STEM.

Table 18: Student Stating the Importance of Diversity in Tech.

Table 19: Professor Stating Why Supporting Women in Tech.



Events such as the Break Into CS Bootcamp and the Whiteboard Campaign may not fit in the traditional definition of WiC events, but the fact that they are so popular among students and are evaluated positively by attendees suggests that a loose definition of WiC as an identity, without membership requirements, may actually result in broader impacts.

WiC Is "Not Super Competitive". It's a Safe Space. Many other college clubs, especially the ones that are more professional-oriented, can be competitive—even if students learn skills together, they also compete with each other when they go to apply the skills in competitions or job searching. In contrast, WiC maintains a good balance with regards to offering professional preparation and providing a safe space for psychological support.

For instance, a WiC participant shared why having a safe space is important for her:

> *"It's nice to have a space where you can really get down to the problem… I think that self-doubt is the biggest thing, like I can't do that. I will always shift the blame to myself… That's a big difference I see between me and my male peers. They will always be like, 'oh, this professor sucks.' Like 'I don't understand because they didn't teach it.' Whereas I'm like, I should have read the book. I should have read that."*

In WiC, people can sit down and share their experiences, the challenges they encounter, and stories of overcoming obstacles and, ultimately, success. Sharing success stories here is not about showing off; rather, it is about sharing advice and helping people figure out their paths. One WiC participant explained what she and her peers did in WiC:

> *"It's like we're trying to be friends with each other. We're trying to like get advice from each other. We're not trying to compete for the same internships. We're not like, I don't know, like competing to win professor's approval or something. We're all kind of in this together… I just didn't want people to brag about their internships rather than helping other people figure out their own problems and stuff."*

Club's members also expressed what they liked about WiC, especially about the safe space aspect.

> *"I really like WiC and I really like what they do and I think having a safe community for girls to explore what they like in tech without judgment from males is really valuable… I understand how it feels like that you're out of place in your classes and that you're like struggling. Cause I went through all of that a lot my freshman, sophomore year."*

For female students in WiC, they have already had a lot of competitions in their classes, and they don't need another place for more competition. Therefore, they come to WiC events for making friends, for seeking support, for being together.

WiC Is a Journey and People Are Carrying It On. For many people, being a woman in computing is not a onetime thing; it is an identity that they carry on. Similarly, for WiC as an organization, it is a journey for many of its members, and people are carrying it on. Through my observation of WiC events and individual interviews with WiC executive board leaders, I identified three ways in which WiC is carried on by people in the club.

Sustaining the Club Through Interactions Between Faculty and Students. One of WiC's recurring events is the Faculty Lunch. The Faculty Lunch is usually held once a quarter, providing WiC members an opportunity to not only eat (free) lunch with their favorite female faculty members in the computer science department, but also learn about how these faculty members become who they are and what they've been through along the way. As discussed above, many female students have self-doubt and often blame themselves for not being smart enough or having not worked hard enough. What they don't know is that the female faculty members they admire and see as role models have

also gone through similar struggles. However, such struggles are not often something students would hear during regular class meeting times, and thus few students would even know about that. Therefore, WiC's Faculty Lunch provides a platform for students to interact with their role models closely and to get confidence and support from these relatable personal journeys. With such a platform, WiC enables its students to receive support from faculty members but at the same time maintains itself as a student-run organization that does not rely heavily on faculty's leadership and involvement. As a result, even if current students graduate and leave, events like this can still help sustaining the connection between faculty and students and furthermore sustaining the club.

Sustaining the Club Through Interactions Between Upperclassmen and Underclassmen. Another WiC event that features the idea of carrying on is the Mentorship Program where underclass mentees are paired with upperclass mentors. The Mentorship Program first started in 2017 as a program for only one quarter in the school year, but it was later transformed into a program where the mentor-mentee relationship would continue at least throughout an entire academic year. The programming chair who was in charge of running the Mentorship Program shared her thoughts on making the event recurring throughout the academic year:

> *"We don't want it to just be like you meet once with your mentor and then you just forget about them. So that's kind of what happened to me my freshman year. I did join the mentorship thing and then I ended up not keeping in touch with my mentor at all."*

Of course, some mentors and mentees might meet up and communicate outside of the dedicated WiC mentorship events, but that is beyond the control of WiC. The leader of the Mentorship Program wanted to at least host one dedicated event each quarter for mentors and mentees to meet, with the hope that this could make both mentors and mentees more accountable.

Another thing that this programming chair did to maximize the benefits of the Mentorship Program was to match mentors and mentees by their interests and their characteristics. For example, she would try to pair mentees who are transfer students with mentors who are transfer students, knowing that mentors who are also transfer students might better relate to questions that mentees have, especially with regards to course enrollment and fitting into new environment.

Through these cycles of mentorship, mentors and mentees build strong connections that can extend even beyond the WiC events. When mentors graduate, mentees who have benefited from the Mentorship Program as mentees may then sign up to be new mentors who can guide new student mentees. This way, the Mentorship Program can still sustain even if senior students leave and new students come in, and it can then help sustaining the club further.

Sustaining the Club Through Interactions Between the Senior Executive Board and the Junior Executive Board. For an organization with a few dozen people, we may often think one executive board with nine leaders is more than enough to serve this community. WiC executive board leaders, however, were not satisfied; they started a

junior executive board in 2018 and began recruiting students passionate about serving the community during freshman or sophomore year.

One of the most challenging issues for many organizations is its sustainability. Often times, organizations with strong leaders may flourish at some point but then fade out quickly as those impactful leaders leave. WiC leadership was also concerned about the sustainability of WiC, and that's why they decided to start the junior board.

WiC executive board leaders who were leading the junior board shared their selection criteria for junior board:

> *"One of the main things we looked for especially was response to why do you want to be on junior board? So if someone was like, 'I want to put this on my resume', we were like, no. But some people genuinely seem to want to build a stronger community and help encourage more women to get involved in things that may challenge them. And those were the people that we tried to pay the most attention to."*

In fact, WiC junior board has been successful in training future WiC executive board leaders. The two presidents of the 2019 executive board were junior board members from the year before, one of the presidents of the 2020 executive board was on junior board the year before, and then the two presidents of the 2021 executive board were again both from WiC junior board.

A WiC president who was on the junior board before becoming a senior executive leader shared why she joined WiC junior board: "I just wanted to see how WiC was run

and I knew that I wanted to be on exec so I thought that (junior board) was a good stepping stone." And junior board is indeed a stepping stone for her—she was on junior board during her freshman year, and then she became treasurer on the senior executive board in her sophomore year, and finally in her junior year she became one of the two presidents of WiC.

Having designed a structure like the junior board ensures that WiC continues to have leaders who are excited and passionate about serving the WiC community. The goal of the junior board is "making connections with underclassmen, making sure they're invested in the community and building relationships with each other." Then, when seniors on WiC executive board are leaving, they no longer need to worry about whether WiC can remain what it is or become better after they leave. They know that they have witnessed the growth of new WiC leaders since their junior board experience, and those new leaders have proved themselves to be the type of leaders that this community needs.

Taken together, WiC provides various events that allow its members to engage and involve in it. It is an identity, a community, a safe space, and a journey.

Research Question 2: What Are the Impacts of WiC?

Now that the question about how students engage in WiC has been answered, I turn to understanding changes brought by WiC to examine WiC's impacts and the mechanism for those impacts. Specifically, I break down impacts by their levels of change—either at the individual level or at the organizational level—and present evidence for changes driven by WiC at each level.

Changes Engendered by WiC at the Individual Level. As discussed earlier in Chapter 2 (Theoretical Motivation and Literature Review), perhaps the most important factor in promoting women's participation in computer science is sense of belonging or sense of community. Women stay in the field if they feel they belong and they leave when they feel not being part of the community. Another psychological factor that keeps coming up in WiC events and in interviews with WiC members is the imposter syndrome (Clance and Imes, 1978). Imposter syndrome is a psychological pattern in which an individual doubts their skills, talents, or accomplishments. It is commonly seen among high-achieving women. Therefore, after a detailed analysis of how students engage in WiC, some measure or evidence of individual students' change with regards to psychological factors (e.g., sense of belonging, imposter syndrome) is needed to support WiC's effectiveness.

To address imposter syndrome, WiC has been co-hosting the imposter syndrome workshop with one of their sponsors, Google, for two years. According to WiC workshop attendees, the imposter syndrome workshop does more than educating students about this concept; it convinces students that experiencing the imposter syndrome does not mean they are not talented, and that even high-achieving people, especially women, often struggle with it.

> *"I think psychologically I definitely struggle with imposter syndrome… I think it took a long time and now I am still struggling with it. I think it was a combination of having people who also felt the same way and sharing in that, um, but also in knowing that we all feel the same way, just going for*

it and trying it and… We just like collide with whatever challenge we come across together and help each other."

The imposter syndrome workshop is not limited to women. The workshop was open to men as well. Sometimes, women find men's attendance at events designed for women to be annoying, but some WiC members felt good about men attending the imposter syndrome workshop. A female participant stated:

"So like the imposter syndrome event, it's good for guys to be there because they can see how they can be able to help… I think in those types of events it's actually good because they're being a respectful person, like they can learn how to be helpful and supportive in a good way."

In addition to addressing imposter syndrome for individuals, WiC also increases women's sense of belonging in the computer science arena more broadly. For instance, one WiC member shared how WiC helped in her sense of belonging in the tech community. Talking to other women who had similar experiences was very helpful:

"I think it has helped me to see that I do have a place in tech and that my voice matters. I don't necessarily have to be like a computer nerd to be in tech. When I came in, I just thought that, you know, I wasn't good enough for it, that I wasn't cut out for it. But then talking to just other women who are in the same boat, I realized it's not about whether you're cut out for it or not necessarily. And that it's important for us to be represented in the

tech community… I do feel more like affirmed and more sense of belonging."

Another person, a WiC executive board leader, also discussed how she felt her identity changed after being in WiC and how she became more connected to the Computer Science Department:

"I feel like I have a place in it (computer science) because before I was kind of just floating around just taking CS classes but not really doing anything in CS. But then being in WiC made me realize like I have an actual position and kind of change the situation some way. I think being in WiC helped me reach out to professors more. It just made me more confident overall to be in the CS department to ask for help, to go to office hours to talk to professors."

Among all the events that WiC hosts, travelling to Grace Hopper Celebration might be a special one. It is the only event where WiC members would spend days living together, far from the university. Many WiC members shared their anecdotes about the Grace Hopper Celebration with me during the trip to Orlando. They also talked about their learnings and takeaways from the Grace Hopper experience in the individual interviews.

"I think just seeing so many other women who are in tech, who are maybe going through similar struggles even if you're in complete different schools, um, having that sort of like community is helpful. I think it was

just really empowering also to see role models. I think that's a big thing, like from our keynote, seeing people who have done it because then you know, you can do it too. And meeting other students who, like I said, have similar sentiments (is helpful).”

Such an exposure to people outside of WiC or outside of the school’s computer science department is a rare opportunity for most students. It is often a new experiential learning experience for students, in which they get to be shadowed by role models in the field, be lectured by speakers from other institutions or from industry, and be accompanied with other fellow students who are also passionate in tech and are eager to learn and grow. At the same time, because it is mostly for females and other gender minorities, Grace Hopper also provides a safe space for female students who go there, which relieves them of the anxiety about being judged by others, especially men. One WiC Grace Hopper attendee stated:

“I think it opens you up to a lot of opportunities that you wouldn't otherwise get. Like you get to talk to recruiters firsthand. So one thing for me is freshman year and sophomore year, I only attended one career fair, I was so nervous. I was like, everyone here is probably judging me. Like they're going to listen into me talking with the recruiter. And they're like, wow, she sounds so stupid. So I felt that way a lot when it came to anything regarding recruiting. I think being at Grace Hopper makes that process a lot easier for me. I don't feel that way anymore. I realized that none of the girls there are going to be judging me. Meanwhile like if I did

that here (at the university), I feel like a lot of the guys would be judging me."

Besides traditional programming-focused skills and job opportunities, Grace Hopper also offers many other opportunities in or related to tech, such as program or project management, technical consulting, banking and trading, etc. Being able to even just learn that such opportunities exist can be beneficial to many students as well. For instance, a student who was not planning to go with the traditional programming path talked about how she felt about Grace Hopper:

"It definitely made me realize that a lot of the boundaries that we place on ourselves are self-imposed. And all of these women were like, they were told repeatedly, you're not going to succeed in this. It's pointless to even try. And they're so successful, they're literally speaking at Grace Hopper. So I guess it helped me realize that not everyone is going to have a traditional set path. And if you kind of choose to deviate from that path, um, you could end up like, I don't know, like having your dreams kind of fulfilled, even if that's cheesy."

Therefore, experiential learning opportunities such as the Grace Hopper Celebration can offer individuals more than the development of technical skills; these experiences can promote psychological development and personal growth. Technical skills are of course important in students' learning, but psychological development can be more crucial in one's development, especially when it removes hurdles or obstacles that prevent individual's growth.

Changes Engendered by WiC at the Organizational Level. As a college club, WiC definitely wants more than impacting individual students. After all, students come and go, and they will all eventually graduate and leave the school to continue on their careers. If WiC's vision is to influence more than one generation or a few generations of students, changes at the organizational level are needed. Ensuring cultural and institutional change can be the most effective approach to sustaining changes in the long run.

The Computer Science Department Welcomes More Students' Voices. One salient theme I heard from WiC executive board leaders is that female computer science students now have more voice in the Computer Science Department—several of the WiC executive board leaders got picked on the CS advisory board, where they met with the department chair, a few faculty members, and some other student representatives to have open conversations and dialogues about issues in the department.

> *"The CS advisory board meeting is just a few students and then (the department chair) is there, (a few professors' names) is there and then a few other CS faculty. So it's much more intimate and we just talk about problems that we hear keep reoccurring and what exactly is going to happen… It's more like what are the problems in the small meetings, we deal with those problems, how do we solve them? And I think they're really invested in hearing the student perspective of what do we want to see it happen as a student."*

Although the computer science department already has town hall that is open to everyone, these small meetings within the CS advisory board is much more focused and intimate. And they talked about not only issues, but also solutions, during these meetings. According to one of the former presidents of WiC who was also on the advisory board, she was selected because she was very involved in WiC and she knew the aspirations and challenges of female students well. She viewed her selection to the CS advisory board as a sign that the department wanted to scale up and help sustain the WiC's efforts, which have helped many students.

Representation of Female Students and Faculty Members. Another organizational level change that is related to the cultural and institutional environment is the representation of female students and female faculty members. Based on most recent data (Fall, 2021) on percentage of female students in the Computer Science Department, overall, 29% of the students majoring in computer science are female. The breakdowns for each class are as follows: 23.2% for freshman, 33.5% for sophomore, 27.7% for junior, and 28.9 for senior. One thing we can notice here is that freshman the class has the lowest percentage of female students, but the numbers go up for upper classes. This interesting change might suggest that WiC, along with other factors of course, may have an impact on how underclassmen perceive the field of computer science and affect their decision to major in computer science, which then lead to increased representation of female students in upper classes.

Besides such departmental data, WiC members also shared their perspectives on women's representation in the department during the interviews. For example, this student talked about her perception of increased number of female students:

> *"I think the number of students is definitely a big change and I think it helps that we now, I think there's definitely more. I think there's more students in general, but I do think. I think the proportion is changing. It's hard for me to tell though because I'm not in like 111 211 (introductory level computer science class). But it is nice to see more people coming to WiC events. When you go to (library) third floor you can see a ton of woman hanging out with the CS department. That's awesome."*

There has also been an important increase in the number of female faculty members. Even during the past three or four years, the computer science department has changed from having only or two female professors to several outstanding female professors that students all admire. A senior WiC member shared what she has seen throughout her four-year time:

> *"Faculty wise, I think when I first came here, Professor A was like pretty much the only person, woman faculty... So Professor A was the one person that you would always go down every time… But since then, Professor B has been a really big figure for a lot of people. They just hired Professor C, awesome. And tons of female students love her. They're just hiring a lot more female faculty, which is really nice to see."*

Reflecting on the multi-level structure of WiC, such social environmental changes at the organizational level would make a difference in WiC's group culture and WiC members' individual psychological feelings for sure. Students claimed that seeing more female faculty was very encouraging. Moreover, as WiC becomes increasingly vocal in the department's decisions, and the demand for more female faculty members grows, these changes are also a collective decision that WiC executive board leaders are part of. Even if they do not have the power or authority to make that decision, their advocacy might be vital in having the department to buy into such a change.

Research Question 3: How Did Changes Occur?

Upon answering research question 2, I have provided evidence for changes driven by WiC both at the individual level and at the organizational level. But understanding change is more than assessing impacts; it is also about interpreting and articulating how changes occurred. To address this research question 3, I relied on my interviews with WiC executive board leaders and attempted to unpack the change process by articulating their leadership strategies and approaches using Kezar's (2014) framework.

Top-down Leadership Strategies. When facing general WiC members, WiC executive board leaders are naturally top-down leaders. All of the top-down leadership strategies reviewed by Kezar were somewhat evident when looking at changes driven by WiC.

Establishing Core Values, Vision or Mission. Having a clear direction for change is crucial, and WiC executive board leaders have the ability to articulate the organizational mission, vision, and values. On the one hand, their mission statement

clearly presents their values, vision, and mission, which I have explored in detail in Chapter 4. On the other hand, WiC executive board leaders also expressed and articulated their vision for the organizational mission during the one-on-one interviews. For example, one of the former presidents of WiC shared what she would prioritize in WiC's mission:

> *"I would prioritize making sure it's inclusive, accessible... Just like making sure there's either two things: supporting an environment where people can build relationships with each other or supporting an environment where we can support us as an exec board with our sponsors. Whatever can support our members."*

The part of inclusive and accessible speaks to what is on the mission statement: "Women in Computing (WiC) is a community for women, non-binary, and trans-folk who are passionate about technology." Likewise, the former president's statement about support corresponds to "help them foster a sense of belonging and solidarity" on the mission statement. Such a motivating vision or mission can become the blueprint for the organizational and ensure change is in the desired direction.

Using Planning Mechanisms. While a vision or mission gives direction, the planning process is also important because it provides an implementation plan and assigns roles and responsibilities to individuals. Weekly WiC executive meetings are the best example of planning mechanisms, in which WiC executive board leaders sit together to go through planning details for each of their events on a weekly basis. Other important documents that are also part of WiC's planning mechanisms include meeting minutes,

transition documents, contact information of sponsors, etc. These planning mechanisms together clarify each executive board leader's responsibility and therefore ensures some degree of accountability for bringing changes forward.

Using Resources and Funding. The issue of resources or funding is somewhat challenging to analyze in the context of WiC, as WiC executive board leaders don't necessarily have the same level of resources and funding as leaders at the university level. However, WiC executive board leaders do raise their own funds through industry and other sponsors. For instance, during the trip to the Grace Hopper Celebration in 2019, the corporate relation chair and a few other WiC executive board leaders prepared sponsor booklets in advance and reached out to companies on-site, seeking additional sponsors for WiC. If successful, sponsors will bring WiC not only financial support, but also professional resources such as on-campus recruiting events or professional workshops. The executive board can then allocate the funding to support WiC's goals and events. Sometimes, there are also fundings from the department, such as the GHC scholarships. WiC executive board leaders are also proactive in negotiating fundings like this with the department and try their best to allocate the funds for students who might benefit most.

Motivating People Through Incentives or Rewards. For WiC members who are essentially just college students, incentives can be as simple as free food. "Who doesn't love free food?" said one WiC executive leaders. Therefore, free food is provided in almost all of the WiC events, either by WiC itself, or by WiC's sponsors. Perhaps some people come to events because they are hungry, but at least throughout my two years of

observation, I did not see anyone who came to WiC events just to pick up free food and left immediately.

Restructuring or Creating Support Structures. I consider WiC's decision of expanding WiC executive board to include one more position in 2020 as an implementation of the strategy of restructuring support structures. That decision was a restructuring for programmatic and service purpose, and the new position and the new structure of WiC executive board is important in distributing responsibilities and ensuring accountability for achieving change.

Hiring and Training of Employees. In the context of WiC, the strategy of hiring and training is not about employees but about underclassmen, because WiC has less hierarchy compared to the department, school, or institution. The junior board, which I have discussed previously in my answer to research question 1, is a great example for this training strategy. As mentioned above, the junior board has become a system where new leaders receive training and mentoring through this stepping stone to WiC senior executive board.

Bottom-up Leadership Strategies. As discussed before, WiC acts as a "bridge" between the individual level female computer science students and the organizational level computer science department. Thus, when facing the Computer Science Department, the School of Engineering, or even higher-level institution leadership, the role that the WiC executive board plays is bottom-up. A similar approach was taken to examine whether bottom-up leadership strategies reviewed by Kezar (2014) were adopted by WiC executive board leaders.

Intellectual Opportunities. This strategy was definitely used by WiC executive board leaders because WiC does host events that provide forums where issues of interest can be intellectually discussed, such as Tech Talks where invited speakers give a short lecture, and Open Dialogues, where members can come together and have honest conversations with their peers or allies, etc. These intellectual opportunities allow WiC executive board leaders, as bottom-up leaders, to foster learnings that align with their change direction and keep members updated on their vision and mission.

Professional Development. The strategy of professional development was already evident even from the network analysis in Chapter 4. One important mission of WiC is to provide professional resources and opportunities, and WiC hosts many professional development workshops (e.g., introduction to GitHub, resume building, interview preparation) to fulfill this mission. These professional development workshops help in generating awareness among WiC members and facilitating implementation of change plans.

Leveraging Curricula and Using Classrooms as Forums. WiC executive board leaders' way of utilizing this strategy was to advertise WiC events through course online learning management system. For example, one member shared in the interview how she first heard about WiC:

> *"I think one of the first times I heard about it (WiC) was through a Piazza post that (the professor) made when I was taking 111 (introductory level programming course), cause I think one of the presidents back then sent her an email asking her to post it in our group in our class Piazza."*

This strategy has been effective in informing new students the existence of WiC and recruiting new members to the group.

Joining and Utilizing Existing Networks. A demonstration of this strategy would be partnering with other on-campus clubs with similar missions or common interests in some of the events. For example, WiC has partnered with Society of Women Engineers (SWE), a club that works with the broader female engineering student community, to host recruiting days. WiC has also partnered with IEEE, a technical professional organization for the advancement of technology, to host the annual Whiteboard Campaign. Compared to SWE and IEEE, WiC is a small organization. Therefore, joining and utilizing SWE's or IEEE's networks can generate broader impacts on campus, which may then lead to successful changes.

Working with Students. As an organization for students, WiC no doubt works with students because its mission is creating and fostering a community for students. Although WiC executive board leaders do also have connections with faculty and staff in the computer science department, or even the Chair of the Computer Science Department and Dean of the School of Engineering, their main planning still focuses on students. After all, female computer science students are the people that WiC's changes are for, and therefore working with students directly may allow changes to happen more organically and quickly.

Hiring Like-Minded People. The WiC junior board is not only evidence of a top-down training strategy; it is also an example of the bottom-up strategy of hiring like-minded people. As mentioned earlier, when selecting junior board members, WiC

executive board leaders were looking for people with similar passion and interest in serving the community of women in computing. This is to ensure that new leaders will have the same commitment and passion for the change that has been started and continue to carry it on for long-term and sustainable impacts.

Gathering Data. The purpose of gathering data is to tell the story of an initiative, raise consciousness, mobilize action, and garner additional support. There are several types of data that WiC executive board leaders collect. For instance, they collect data on students' performance in on-site interviews at Grace Hopper Celebration after students come back from the Grace Hopper Celebration to tell the story of how successful the effort of sending students to Grace Hopper is, which may then lead to more funding for conferences from WiC's sponsors or the computer science department. They also collect check-in information and feedback forms for each event, so that they can let the Computer Science Department know how many active participants are in this community and what impacts they are making. For WiC executive board leaders, gathering data alone is not the endpoint; using the data collected to tell a good story that can engender greater impacts is what's more important.

Garnering Resources. In WiC, financial support from sponsors is used to mobilize people—providing a way to bring people together for events, fund meetings and conferences (e.g., Grace Hopper Celebration), and form allies in the industry who might be able to support WiC in the long run.

Partnering with Influential External Stakeholders. Influential external stakeholders for WiC can include successful alumni who currently work for large

companies in the industry, local communities such as Girls Who Code, or even political leaders in the area who care about diversity and inclusion. I did not observe interactions between WiC and local political leaders, but I did see lots of partnership between WiC and its alumni or local communities. These partnerships might be able to help WiC executive board leaders as change agents to overcome some internal resistance by advocating for WiC.

WiC Executive Board as a Collective Leadership. Besides identifying strategies and approaches utilized by WiC executive board leaders, it is also important to recognize WiC executive board as a collective leadership group rather than solely individual leaders. Although leaders on the executive board all have their own positions and responsibilities, their leadership in the change process is considered to be a collective group process, rather than only being exercised by individuals. Based on my observation of WiC's weekly executive board meetings, all of the decisions were discussed and approved by the entire board through group discussion and consensus even if sometimes the plans were proposed by individuals. Many researchers have highlighted the advantages of such collective leadership, which include increased problem-solving capabilities, greater creativity and organizational effectiveness, increased motivation and dedication by members of leadership groups, and greater satisfaction with decision-making, etc. (Bensimon and Neumann 1993; Pearce and Conger 2003).

Resistance and Obstacles. Even though WiC has been successful in its growth and development and has made great impacts on both individual female computer science students and the computer science department, the efforts have not been without

obstacles and resistance. In the interviews, WiC executive board leaders discussed challenges and obstacles from their perspectives, as well as some of the group decisions they have made to overcome those challenges and obstacles. I again used Kezar's (2014) framework to examine these challenges and obstacles from a change theory perspective.

Social Cognition Obstacles. From a social cognition perspective, obstacles emerge because individuals' old mental models are not updated along with new changes. For WiC, this again has to do with individual students' feeling of incompetence. Many students entered an elite university after being the top student in their middle school or high school. When they are in the computer science classrooms with students who have more experience, the feeling of not being able to excel discouraged many female students. For instance, a WiC participant shared her social cognitive challenge:

> *"I think that challenge comes from girls feeling discouraged and then feeling like they don't belong here or that they can't succeed. Maybe they can be mediocre at it or average at it, they think, but they can't ever succeed or excel. And that's probably what I think people struggle."*

Fortunately, as discussed earlier, WiC has partnered with Google to co-host imposter syndrome workshop to address the issue of feeling not good enough. Besides trying to shift mental models for college students, WiC's outreach events also attempt to address this challenge for younger girls. Here is what the community outreach chair from WiC executive board said:

> *"I think I affect a lot of high schoolers and middle schoolers because when I go there, they actually really listened to me… I think a lot of it is because I go to (university's name), like a lot of people in this area in the suburbs want to go there. So they automatically respect me. So then they take my word as truth kind of. So I'm like, yeah, you gotta stick it out. You gotta ignore all the people who say you can't do it and then just go for it if it's what you really want to do."*

These strategies work because as WiC hosts these events, they inform people who are involved in the change process – female computer science students or even younger girls who are interested in pursuing computer science – that WiC is working to make a difference.

Cultural Obstacles. From a cultural change perspective, one element of the Computer Science Department culture is that male students can sometimes be condescending or like to show off. Such culture then results in female students' values and beliefs that the field of computer science does not welcome women, which can be viewed as an example of cultural obstacles. For instance, one female student described how she felt looked down when going to male TA's office hours:

> *"When I went to office hours for example, I would kind of feel like male TAs especially would talk down to me a little bit... That's what kind of discouraged me from going to office hours in the first place, cause nobody wants to be made to feel stupid. And I hated that feeling. So I just kind of chose to work on my own."*

Another example of cultural obstacles is that when companies come to recruit on campus, there are usually many more male students than female students, and female students may feel that men are judging them, their skills and their performances.

There are several approaches that WiC has taken to overcome such obstacles. For one, WiC has been encouraging more of its members to become TAs or peer mentors for computer science classes or to offer study events, so that those who feel uncomfortable with male TAs can get help from female peers. For another, WiC has tried very hard to fund as many female students as possible each year to the Grace Hopper Celebration, where most opportunities are dedicated to women. As mentioned above, students often feel the culture at Grace Hopper is more welcoming for females.

Institutional Obstacles. This type of obstacles does not seem that salient for WiC because institutional norms have evolved to advocate diversity and inclusion campus wide. Instead of different stakeholders having contradictory stances, stakeholders at the institution are consistent in their support of diversity and inclusion initiatives, including broadening participation of women in computer science. This is fortunate for WiC, because institutional resistance or obstacles can be the hardest to overcome, due to the complexity in management, politics, and other factors. However, even if WiC benefits from such institutional norms and initiatives, challenges still exist and there is still a long way to go institutional-wide, state-wide, or even nation-wide.

Discussion

Results from this study reveal that Women-in-Computing (WiC) club provides various programs and events that allow female students in computer science to fully engage in it and to learn and grow. For these students, WiC is an identity, a community, a safe space, and a journey. Moreover, results also suggest that changes driven by WiC have brought impacts to both individual level female computer science students and organizational level computer science departments. Furthermore, by applying Kezar's (2014) framework for understanding change, both top-down and bottom-up leadership approaches have been identified and interpreted in WiC executive board leaders' decisions and practices and have been shown to be effective. In addition, resistance and obstacles related to social cognition, cultural, and institutional theories of change have been examined and evaluated, along with WiC's approaches to overcome those challenges.

Connection to Study 1 in Chapter 4

The results of this chapter are related to those of Chapter 4 (network analysis) and help to shed light on those findings. For example, both studies highlight the degree to which values and practices reflected on Women-in-CS groups' website align with their actual practices. To recall, the value of community and the prevalence of social events are the primary aspects of the mission of Women-in-CS groups based on information available on their websites. In the present study, I found that the idea of WiC being a community has been deeply embedded in WiC executive board leaders' vision and mission for this organization, and the WiC executive board leaders have put in

considerable effort and developed different strategies to ensure that changes they are fostering are moving toward this direction.

Categories identified by the study in Chapter 4, either values or programs/events, are also recognizable in the particular WiC investigated in Chapter 5. The four core values from Chapter 4—community, opportunity, equality/inclusion, and encouragement/support—were either mentioned by WiC executive board leaders as they described WiC's culture and what they wanted to accomplish as WiC leaders, or manifested in various programs and events that WiC hosts. For instance, the Whiteboard Campaign, in which WiC members asked students on campus to write out their why they support women in STEM, is a good example for the value of equality/inclusion. This finding even extends beyond women in computer science; it is more broadly relevant to equality and inclusion across all STEM domains. Similarly, the eight types of programs/events from Chapter 4—mentorship, Grace Hopper Celebration, community outreach, corporate, advocacy, social, technical, and faculty—are almost all available in this WiC. Some of the events or programs were brought up by WiC members in interviews over and over again, emphasizing their engagement in WiC and the benefits of these programs.

A New Approach for Examining Changes in College Clubs

Although organizational change theories have been used extensively to examine reform in higher education (e.g., Awbrey, 2005; Gumport, 2000; Kezar, 2011; Kezar, 2014), this perspective has rarely been used to examine changes initiated by college clubs. Therefore, this study is a new attempt in applying organizational change theories in

the context of one particular college club and unpacking change process by closely examining levels of change, agency of change, and resistance and obstacles. This cross-level approach is useful for not only describing change phenomenon and change impacts, but also articulating change process and change mechanisms.

As diversity and inclusion initiatives become increasingly important in higher education, finding new approaches for understanding change and then facilitating change merit more attention. Because college clubs run by students act as a natural bridge between students who engage in the clubs and higher-level institutional leaders who oversee the clubs, the cross-level perspective can be extremely valuable in providing actionable insights for group level changes that serve both individual level and organizational level.

Moreover, the perspective of tight-loose cultures (Gelfand, 2018) also adds nuances to understand how and why changes occurred in this WiC. On the one hand, the analysis of leadership and change agents indicates that WiC's culture has some tight components—there is a structured leadership board who has the position of authority and coordinates and unifies the events and the participants in the group. On the other hand, WiC can also be seen as a loose culture because WiC is an identity-based rather than a membership-based group, and there is merely any requirement to be part of it. Such a loose culture allows WiC to be more open to new ideas, to new people, and to new changes. There are situations when tight cultures are better than loose cultures, or vice versa, but WiC seems to balance this tight-loose trade-off well. Both tight and loose confer important strengths to WiC, and a good balance of both tight and loose enables

WiC to not only have structures to engender changes but also openness to accept changes.

Limitations

This study, though using a different approach to explore the same issue as the previous study in Chapter 4 (network analysis), only examines one particular Women-in-Computing club. Even if alignment has been identified between what this WiC actually does and what they say on their website with regards to missions and practices, it does not allow us to make the claim that all Women-in-CS groups are the same and that their actual practices are all consistent with information on their websites. Future research should look at some other Women-in-CS groups to see if similar claims still hold.

Another limitation is that due to unsuccessful data collection, the survey results did not yield to additional evidence or insights on change in students' sense of belonging in computer science. Across the three distributions of the survey, only one student completed the survey all three times, which is disappointing and cannot provide meaningful results. Therefore, future research needs to reconsider data collection approach to ensure continuity of multiple-time distribution of survey.

Furthermore, because I did not anticipate seeing men participating in WiC events, my observations, interviews, and surveys did not include a question on gender identity. I was only able to speculate individual's gender identity based on their appearances, which can be problematic and needs to be better considered in future studies.

Conclusion

This study is an attempt to apply organizational change theories in the context of college clubs to examine and evaluate changes initiated by one particular Women-in-CS group. By taking a cross-level, multi-faceted perspective, I explored how students engage in Women-in-CS club, what impacts this club has, and the underlying change mechanisms. Results from this study reveal that Women-in-Computing (WiC) clubs provide various programs and events that allow female students in computer science to fully engage in them and to learn and grow. For these students, WiC is an identity, a community, a safe space, and a journey. Moreover, results also suggest that changes driven by WiC have brought impacts to both individual level female computer science students and organizational level computer science department. Furthermore, by applying Kezar's (2014) framework for understanding change, both top-down and bottom-up leadership approaches have been identified and interpreted in WiC executive board leaders' decisions and practices and have been shown to be effective. In addition, resistance and obstacles related to social cognition, cultural, and institutional theories of change have been examined and evaluated, along with WiC's approaches to overcome those challenges.

However, many questions remain regarding how representative this particular WiC is, whether findings from this WiC can be expanded or generalized to other Women-in-CS groups or even other types of college clubs for diversity and inclusion missions. Although those might not be the focus of this study, further research is required to fully understand how best to harness the power of college student clubs that allow for

broader long-term impacts related to issues of underrepresentation of women in STEM, or more general diversity and inclusion issues.

Chapter 6: Discussion, Limitations, and Future Directions

Chapter 4 and Chapter 5 have presented in detail the results of the two studies on Women-in-Computer Science (Women-in-CS) clubs respectively. Although the two studies used different research methods, they are theoretically related, and they both addressed the issue of the lack of females in computer science through examining Women-in-CS clubs.

Findings from the network analysis in Chapter 4 revealed the current status of Women-in-CS clubs. Overall, the Women-in-CS clubs emphasize on the value of community, and their social events tend to be the most popular and core events among all the clubs. Findings also suggested that the values and the practices highlighted and emphasized on Women-in-CS clubs' websites are related, and both the values and practices speak to the two deficits identified by previous research on the issue of gender imbalance in computer science and the attempted remedies—deficits in women and deficits in computer science (Lagesen, 2011).

Then in Chapter 5, findings from the in-depth study of one particular Women-in-Computing (WiC) club provided more nuances and details on not only students' engagement in the club, but also the impacts of WiC and how those changes occurred. Specifically, Kezar's (2014) organizational change framework was applied to analyze and interpret how changes driven by WiC fit with different theories of change, as well as various elements of change including levels of change, agency of change, and resistance and obstacles.

Nevertheless, one of the goals of this dissertation that has not been addressed in Chapter 4 and Chapter 5 is how these findings may provide insights on identifying and deriving design principles that could further benefit similar college clubs or organizations that have a common interest in broadening participation of women in STEM or more general diversity and inclusion initiatives. And that is what this current chapter will discuss.

Principle 1: Allowing Organizations to Be Identity-Based Rather Than Membership-Based

If we recall the results from Chapter 4, some of the college Women-in-CS clubs are official chapters of ACM-W (Association for Computing Machinery – Woman), which tend to have finer defined membership for the organizations. However, as discussed in Chapter 5, the particular WiC I researched has no membership—anyone who self-identifies as doing computing or as interested in computing can be part of WiC. Instead of strictly limiting access to only computer science majors, such an identity-based structure ensures the organization's inclusivity and accessibility. This in fact opens up more possibilities for students, and it can potentially lead to broader impacts. For example, even from this one WiC, several students have shared that their participation in WiC started before they became a computer science major and that their participation in WiC in fact influenced how they perceived the field of computer science as well as their later decision to finally switch majors. Oftentimes, people choose not to study a certain major not because they don't like it, but because they don't know about it, and they choose to stay in their comfort zone. The open-membership organizational structure gives

these people an opportunity to get first-hand experience in what being a woman in computer science feels like and what kind of support they can get, which might then be crucial in students' decisions to study computer science.

This identity-based community also fits the definition of a community of practice, which was discussed in more detail in Chapter 2. A community of practice is a group of people who form a community for a shared concern or passion for something they do as they interact regularly (Allee, 2000; Lave, 1988; Wenger, 1998), and the three main characteristics shaping community of practices are mutual engagement, a joint enterprise, and a shared repertoire (Wenger, 1998). There is no boundary in terms of who can be part of the community, as long as participants engage in the community for a shared concern or passion.

Principle 2: Having Leaders Who Use Both Top-Down and Bottom-Up Leadership Strategies

Although leadership may not be a panacea for change, leaders as change agents are probably the most important facilitators in the change process. Based on results from Chapter 5, having leaders who connect with both the individual level computer science students and the organizational level computer science departments and use both top-down and bottom-up leadership strategies can be effective in initiating and continuing changes.

Organizations that want to maximize their influence should be cautious in selecting leaders. If leaders only work top-down, they might miss the opportunity to scale

up the changes they are working towards, even if changes could be salient within the groups. If leaders only work bottom-up, they might not have the position of authority to initiate and implement certain change plans. Therefore, having leaders who use both top-down and bottom-up strategies, and connect well with both the individuals in the group as well as higher-level administrators, would be an ideal approach to ensuring successful changes and broadening impacts.

Principle 3: Modeling from Successful Clubs

One important finding suggested by results from Chapter 4 is that although many of the Women-in-CS groups are still developing, some have appeared to be more "mature" in their structures, based on their stated missions and practices on the website. The characteristics of these clubs are that they are more comprehensive in articulating their values and practices, at least based on the information available on their websites, which then made them more "central" in the examined networks.

The particular WiC that I conducted my research on is, in fact, one of the most "central" clubs in terms of its practices, as indicated by eigenvector centrality calculation in Chapter 4. The in-depth study in Chapter 5 has suggested that this particular WiC is indeed a successful group—their actual practices do align with the missions and visions they express on their website, and they have positive impacts on both the individual level and the organizational level.

Thus, although I do not have evidence for other Women-in-CS clubs' actual practices, it is appropriate to speculate that "central" clubs identified by the network

analysis could be successful models for Women-in-CS clubs. Learning from these clubs and modeling them might be an easy way to start a group with similar missions or common interests from scratch.

Nevertheless, the principles I summarized above are not gold standards for Women-in-CS clubs or other college clubs for diversity and inclusion initiatives. My purpose of identifying them is to provide some suggestions for similar groups based on what I learned from the network analysis of 50 Women-in-CS clubs and the in-depth study of one particular WiC. Considering each institution's unique characteristics and constraints, it is impossible to set one perfect model or structure that can work at every single institution. Rather, such an approach of identifying design principles offers empirical-based perspectives that might help in supporting, sustaining, and scaling efforts for broadening women's participation in computer science.

Limitations

This dissertation, though using a novel analytical framework and converging research methods, still has several limitations. First of all, due to limited time and resources for research, the two studies in this dissertation both suffer from a constrained sample. The Women-in-CS clubs in both studies are all from elite national universities, which renders a question of whether such groups and the changes they drive are applicable in liberal arts colleges, other four-year institutions, or even community colleges. However, based on publicly available information on the internet, such groups do exist in other types of institutions as well. Future research can include groups in different types of institutions in their analyses for a full picture of Women-in-CS clubs.

Secondly, although the ethnographic study in Chapter 5 was purposely designed to span two consecutive years to allow observation of changes, two years is still a very limited timespan with regards to institutional change cycles as well as organization's development. If possible, future research may expand the research timeline to more years, which may allow for more iterations of the organizational design and more cycles of change. Thirdly, this dissertation relies heavily on the theoretical framework of organizational change in higher education reform. Further research is needed to explore whether there are other conceptual frameworks or theoretical models that are more appropriate in the context of such research, and to provide empirical evidence for applying those perspectives. Last but not least, the scope of this work is limited to women in computer science, but there are many other challenging issues in higher education spaces with regards to diversity and inclusion that merit attention as well. Perhaps in the future, such an organizational change perspective and a cross-level analysis approach can be applied to research in different settings to examine and interpret changes related to diversity and inclusion.

Conclusion and Future Directions

In summary, my dissertation focuses on one attempt to redress the lack of women in computer science—Women-in-Computer Science (Women-in-CS) or Women-in-Computing (WiC) college clubs. Drawing on organizational change theories, I ask: What are some characteristics of the Women-in-CS clubs and how do students engage them? Do they engender changes? If so, how? I explored these research questions through two theoretically connected but methodologically different studies, using thematic network

analysis and ethnography respectively. Through a cross-level analysis, I argue that Women-in-CS clubs' mission statements and practices directly speak to the challenges of gender inequality in computer science. For students, Women-in-CS club is an identity, a community, a safe space, and the beginning of a career-long practice of mentoring future women in computer science. Moreover, changes driven by such clubs have brought impacts to both the individual level female computer science students and the organizational level computer science departments. Both top-down and bottom-up leadership approaches have been used by these clubs to overcome resistance and obstacles related to social cognition and cultural and institutional theories of change. Furthermore, design principles have been derived and identified to shed light on best practices for college clubs with similar goals. This dissertation offers a new perspective on applying organizational change theories in the context of college clubs and contributes to the broader research community on diversity, equity, and inclusion in higher education.

This chapter concludes my dissertation, but it is not an end for my research career. There are many remaining issues identified alone in this dissertation that I hope to continue researching, as laid out in the paragraphs above. Moreover, this dissertation, along with my other research experiences in my graduate school, has helped shape more broadly my research interest in diversity and inclusion in higher education. For example, besides the lack of female students and faculty in computer science, one of the most significant and intransigent socio-political challenges facing higher education and workforce development more broadly is the dearth of historically underrepresented

minorities (URMs) in STEM faculty positions in the United States. And I would like to use the research methods and the analytical frameworks that I learned throughout conducting my dissertation to study the issue of underrepresentation in STEM. Furthermore, there is much more I can do with all that graduate study has equipped me with: curiosity, creativity, and critical thinking. And I would hope to bring all these with me in my future endeavors.

References

Allee, V. (2000). Knowledge networks and communities of practice. *OD Practitioner, 32*(4), 4-13.

Alvarado, C., & Dodds, Z. (2010). Women in CS: an evaluation of three promising practices. In *Proceedings of the 41st ACM Technical Symposium on Computer Science Education* (pp. 57-61). ACM.

Alvarado, C., Dodds, Z., & Libeskind-Hadas, R. (2012). Increasing women's participation in computing at Harvey Mudd College. *ACM Inroads, 3*(4), 55-64.Alvarado, C., & Judson, E. (2014). Using targeted conferences to recruit women into computer science. *Communications of the ACM, 57*(3), 70-77.

Astin, A. W. (1977). *Four Critical Years. Effects of College on Beliefs, Attitudes, and Knowledge.* San Francisco, CA: Jossey-Bass.

Astin, A. W. (1984). Student involvement: A development theory for higher education. *Journal of College Student Personnel, 25*, 297–308.

Astin, A. W. (1993). *What Matters in College? Four Critical Years Revisited.* San Francisco, CA: Jossey-Bass.

Astin, A. W. (1996). Involvement in learning revisited: Lessons we have learned. *Journal of College Student Development, 37*, 123–134.

Atkinson, P., & Coffey, A. (2004). Analysing documentary realities. *Qualitative Research, 3*, 77-92.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist*, *37*(2), 122-147.

Barrat, A., Barthelemy, M., Pastor-Satorras, R., & Vespignani, A. (2004). The architecture of complex weighted networks. *Proceedings of the National Academy of Sciences*, *101*(11), 3747-3752.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*(3), 497-529.

Bolger, N., Zuckerman, A., & Kessler, R. C. (2000). Invisible support and adjustment to stress. *Journal of Personality and Social Psychology*, *79*(6), 953-961.

Borgatti, S. P., Everett, M. G., & Johnson, J. C. (2013). *Analyzing Social Networks.* Thousand Oaks, CA: Sage.

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, *9*(2), 27-40.

Celik, H., & Ipcioglu, I. (2007). Gender differences in the acceptance of information and communication technologies: the case of internet usage. *International Journal of Knowledge and learning*, *3*(6), 576-591.

Chen, J. M., & Hamilton, D. L. (2015). Understanding diversity: The importance of social acceptance. *Personality and Social Psychology Bulletin*, *41*(4), 586-598.

Cheryan, S., Drury, B. J., & Vichayapai, M. (2013). Enduring influence of stereotypical computer science role models on women's academic aspirations. *Psychology of Women Quarterly*, *37*(1), 72-79.

Cheryan, S., Plaut, V. C., Davies, P. G., & Steele, C. M. (2009). Ambient belonging: how stereotypical cues impact gender participation in computer science. *Journal of Personality and Social Psychology*, *97*(6), 1045-1060.

Cohen, G. L., & Garcia, J. (2008). Identity, belonging, and achievement: A model, interventions, implications. *Current Directions in Psychological Science*, *17*(6), 365-369.

Cohoon, J. M., & Aspray, W. (2006). A critical review of the research on women's participation in postsecondary computing education. In J. M. Cohoon & W. Aspray (Eds.), *Women and Information Technology: Research on Underrepresentation* (pp. 137–180). Cambridge, MA: MIT Press.

Corbett, C., & Hill, C. (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. Washington, DC: American Association of University Women.

Csardi, G., & Nepusz, T. (2006). The igraph software package for complex network research. *InterJournal, Complex Systems*, *1695*(5), 1-9.

Dar-Nimrod, I., & Heine, S. J. (2006). Exposure to scientific theories affects women's math performance. *Science*, *314*(5798), 435-435.

Derby, D. C. (2006). Student involvement in clubs and organizations: An exploratory study at a community college. *Journal of Applied Research in the Community College*, *14*(1), 39-45.

Dewey, J. (1938). *Experience and Education.* New York, NY: Simon and Schuster.

Djonko-Moore, C. M., Leonard, J., Holifield, Q., Bailey, E. B., & Almughyirah, S. M. (2018). Using culturally relevant experiential education to enhance urban children's knowledge and engagement in science. *Journal of Experiential Education*, *41*(2), 137-153.

Dryburgh, H. (2000). Underrepresentation of girls and women in computer science: Classification of 1990s research. *Journal of Educational Computing Research*, *23*(2), 181-202.

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist*, *41*(10), 1040.

Easley, D., & Kleinberg, J. (2010). *Networks, Crowds, and Markets* (Vol. 8). Cambridge, UK: Cambridge University Press.

Foubert, J. D., & Grainger, L. A. (2006). Effects of involvement in clubs and organizations on the psychosocial development of first-year and senior college students. *NASPA Journal*, *43*(1), 166-182.

Gelfand, M. (2018). *Rule Makers, Rule Breaker: How Tight and Loose Cultures Wire Our World.* New York, NY: Scribner.

Good, C., Aronson, J., & Harder, J. A. (2008). Problems in the pipeline: Stereotype threat and women's achievement in high-level math courses. *Journal of Applied Developmental Psychology*, *29*(1), 17-28.

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, *102*(4), 700-717.

Gürer, D., & Camp, T. (2002). An ACM-W literature review on women in computing. *ACM SIGCSE Bulletin*, *34*(2), 121-127.

Harris, S.G. (1996). Organizational culture and individual sensemaking: a schema-based perspective, in J.R. Meindl, C. Stubbart, and J.F. Poroc (eds.) *Cognition in Groups and Organizations*, London, UK: Sage.

Hausmann, L. R., Schofield, J. W., & Woods, R. L. (2007). Sense of belonging as a predictor of intentions to persist among African American and White first-year college students. *Research in Higher Education*, *48*(7), 803-839.

Hawkley, L. C., & Cacioppo, J. T. (2010). Loneliness matters: A theoretical and empirical review of consequences and mechanisms. *Annals of Behavioral Medicine*, *40*(2), 218-227.

He, J. & Freeman, L. (2009). Are men more technology oriented than women? The Role of Gender on the Development of General Computer Self-Efficacy of College Students. *Journal of Information Systems Education*, *21*(2), 203-212.

Hunter, A. B., Laursen, S. L., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, *91*(1), 36-74.

Inzlicht, M., & Ben-Zeev, T. (2000). A threatening intellectual environment: Why females are susceptible to experiencing problem-solving deficits in the presence of males. *Psychological Science*, *11*(5), 365-371.

Irani, L. (2004). Understanding gender and confidence in CS course culture. *ACM SIGCSE Bulletin, 36*(1), 195-199.

Jepson, A., & Perl, T. (2002). Priming the pipeline. *ACM SIGCSE Bulletin, 34*(2), 36-39.

Kesebir, S., Uttal, D. H., & Gardner, W. (2010). Socialization: Insights from social cognition. *Social and Personality Psychology Compass*, *4*(2), 93-106.

Kezar, A. (2011). *Understanding and Facilitating Organizational Change in the 21st Century: Recent Research and Conceptualizations: ASHE-ERIC Higher Education Report, Volume 28, Number 4* (Vol. 155). New York, NY: John Wiley & Sons.

Kezar, A. (2013). *How Colleges Change: Understanding, Leading, and Enacting Change*. London, UK: Routledge.

Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development.* Englewood Cliffs, NJ: Prentice-Hal.

Lagesen, V. (2011). Getting women into computer science. In Sorensen, K., Faulkner, W., & Rommes, E. (Eds.). *Technologies of Inclusion: Gender in the information society.* Trondheim, Norway: Tapir Academic Press.

Lave, J. (1988). *Cognition in Practice: Mind, Mathematics and Culture in Everyday Life*. Cambridge, UK: Cambridge University Press.

Leslie, S. J., Cimpian, A., Meyer, M., & Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science*, *347*(6219), 262-265.

Lewis, K. L., Stout, J. G., Finkelstein, N. D., Pollock, S. J., Miyake, A., Cohen, G. L., & Ito, T. A. (2017). Fitting in to move forward: Belonging, gender, and persistence in the physical sciences, technology, engineering, and mathematics (pSTEM). *Psychology of Women Quarterly*, *41*(4), 420-436.

London, B., Rosenthal, L., Levy, S. R., & Lobel, M. (2011). The influences of perceived identity compatibility and social support on women in nontraditional fields during the college transition. *Basic and Applied Social Psychology*, *33*(4), 304-321.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE—Life Sciences Education*, *6*(4), 297-306.

MacDonald, G., & Leary, M. R. (2005). Why does social exclusion hurt? The relationship between social and physical pain. *Psychological Bulletin*, *131*(2), 202.

Mahoney, J. L., & Cairns, R. B. (1997). Do extracurricular activities protect against early school dropout?. *Developmental Psychology*, *33*(2), 241.

Margolis, J., & Fisher, A. (2002). *Unlocking the Clubhouse: Women in Computing.* Cambridge, MA: MIT Press.

Martin, J. (1992). *Cultures in Organizations: Three Perspectives*, New York, NY: Oxford University Press.

Martin, P. (2001). 'Mobilizing Masculinities': Women's Experiences of Men at Work. *Organization*, *8*(4), 587-618.

Maslow, A. (1968). Some educational implications of the humanistic psychologies. *Harvard Educational Review*, *38*(4), 685-696.

Master, A., Cheryan, S., & Meltzoff, A. N. (2016). Computing whether she belongs: Stereotypes undermine girls' interest and sense of belonging in computer science. *Journal of Educational Psychology*, *108*(3), 424-437.

McMillan, D. W., & Chavis, D. M. (1986). Sense of community: A definition and theory. *Journal of Community Psychology*, *14*(1), 6-23.

Menzel, S., & Frieze, C. (2018). Experiencing Research Through OurCS: Opportunities for Undergraduate Research in Computer Science. In *2018 Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)* (pp. 1-4). IEEE.

Menzel, S., Siek, K. A., & Crandall, D. (2019). Hello Research! Developing an Intensive Research Experience for Undergraduate Women. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (pp. 997-1003). ACM.

Microsoft Corporation. (2012). A National Talent Strategy: Ideas for Securing U.S. Competitiveness and Economic Growth.

Monge, P. R., & Contractor, N. S. (2003). *Theories of Communication Networks*. New York, NY: Oxford University Press.

Monge, P. R., & Eisenberg, E. M. (1987). Emergent communication networks. In E M. Jablin, L. L. Putnam, K. H. Roberts, & L. W. Porter (Eds.), *Handbook of organizational communication: An interdisciplinary perspective* (pp. 304-342). Newbury Park, CA: Sage.

Morgan, G. (1986). *Images of Organization*, Newbury Park, CA: Sage.

Moore, J., Lovell, C. D., McGann, T., & Wyrick, J. (1998). Why involvement matters: A review of research on student involvement in the collegiate setting. *College Student Affairs Journal*, *17*, 4–17.

Murphy, M. C., Steele, C. M., & Gross, J. J. (2007). Signaling threat: How situational cues affect women in math, science, and engineering settings. *Psychological Science*, *18*(10), 879-885.

National Academies of Sciences, Engineering, and Medicine. (2018). *Assessing and responding to the growth of computer science undergraduate enrollments*. Washington, DC: National Academies Press.

National Center for Education Statistics. (2015). *IPEDS: Integrated Postsecondary Education Data System.* Washington, DC: U.S. Department of Education.

National Center for Education Statistics. (2018). *IPEDS: Integrated Postsecondary Education Data System.* Washington, DC: U.S. Department of Education.

Nguyen, A., & Lewis, C. M. (2020, February). Competitive enrollment policies in computing departments negatively predict first-year students' sense of belonging, self-efficacy, and perception of department. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education* (pp. 685-691).

Nosek, B. A., Banaji, M. R., & Greenwald, A. G. (2002). E-research: Ethics, security, design, and control in psychological research on the internet. *Journal of Social Issues, 58*(1), 161-176.

Nyame-Mensah, A. (2015). Strengthening the computing research pipeline through minority participation: The case for undergraduate research experiences. In *2015 Research in Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT)* (pp. 1-7). IEEE.

Osterman, K. F. (2000). Students' need for belonging in the school community. *Review of Educational Research, 70*(3), 323-367.

Piaget, J. (1964). Part I: Cognitive development in children: Piaget development and learning. *Journal of Research in Science Teaching*, *2*(3), 176-186.

Pittman, L. D., & Richmond, A. (2007). Academic and psychological functioning in late adolescence: The importance of school belonging. *The Journal of Experimental Education*, *75*(4), 270-290.

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science*, *316*(5824), 548-549.

Sackrowitz, M. G., & Parelius, A. P. (1996). *An Unlevel Playing Field: Women in the Introductory Computer Science Courses* (Vol. 28, No. 1, pp. 37-41). ACM.

Sax, L. J., Blaney, J. M., Lehman, K. J., Rodriguez, S. L., George, K. L., & Zavala, C. (2018). Sense of belonging in computing: The role of introductory courses for women and underrepresented minority students. *Social Sciences*, *7*(8), 122-144.

Schein, E.H. (1985). *Organizational Culture and Leadership: A Dynamic View*, San Francisco, CA: Jossey-Bass.

Scragg, G., & Smith, J. (1998). A study of barriers to women in undergraduate computer science. *ACM SIGCSE Bulletin*, *30*(1), 82-86.

Seymour, E., & Hewitt, N. M. (1997). *Talking About Leaving: Why Undergraduates Leave the Sciences.* Boulder, CO: Westview Press.

Shaw, K.A. & Lee, K.E. (1997). Effecting change at Syracuse University: the importance of values, missions, and vision, *Metropolitan Universities: An International Forum, 7*(4), 23–30.

Smith, J. L., Lewis, K. L., Hawthorne, L., & Hodges, S. D. (2013). When trying hard isn't natural: Women's belonging with and motivation for male-dominated STEM fields as a function of effort expenditure concerns. *Personality and Social Psychology Bulletin*, *39*(2), 131-143.

Solomon, D., Battistich, V., Kim, D. I., & Watson, M. (1996). Teacher practices associated with students' sense of the classroom as a community. *Social Psychology of Education*, *1*(3), 235-267.

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology*, *35*(1), 4-28.

Spiegel, D., Kraemer, H., Bloom, J., & Gottheil, E. (1989). Effect of psychosocial treatment on survival of patients with metastatic breast cancer. *The lancet*, *334*(8668), 888-891.

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist*, *52*, 613–629.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African-Americans. *Journal of Personality and Social Psychology, 68*, 797–811.

Stephens, N. M., Fryberg, S. A., Markus, H. R., Johnson, C. S., & Covarrubias, R. (2012). Unseen disadvantage: how American universities' focus on independence undermines the academic performance of first-generation college students. *Journal of Personality and Social Psychology*, *102*(6), 1178-1197.

Stout, J. G., Dasgupta, N., Hunsinger, M., & McManus, M. A. (2011). STEMing the tide: using ingroup experts to inoculate women's self-concept in science, technology, engineering, and mathematics (STEM). *Journal of Personality and Social Psychology*, *100*(2), 255-270.

Taylor, H. G., & Mounfield, L. C. (1994). Exploration of the relationship between prior computing experience and gender on success in college computer science. *Journal of Educational Computing Research*, *11*(4), 291-306.

Terenzini, P. T., Pascarella, E. T., & Blimling, G. S. (1996). Students' out-of-class experiences and their influence on learning and cognitive development: A literature review. *Journal of College Student Development*, *37*, 149–162.

Walton, G. M., & Cohen, G. L. (2007). A question of belonging: race, social fit, and achievement. *Journal of Personality and Social Psychology*, *92*(1), 82-96.

Walton, G. M., Logel, C., Peach, J. M., Spencer, S. J., & Zanna, M. P. (2015). Two brief interventions to mitigate a "chilly climate" transform women's experience, relationships, and achievement in engineering. *Journal of Educational Psychology*, *107*(2), 468-485.

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems Thinker*, *9*(5), 2-3.

Wright, R. N., Nadler, S. J., Nguyen, T. D., Sanchez Gomez, C. N., & Wright, H. M. (2019). Living-learning community for women in computer science at Rutgers. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (pp. 286-292). ACM.

Wright, R. N., Stout, J., Cochran, G., Nguyen, T., & Sanchez Gomez, C. (2018). Computer Science Living-Learning Community for Women at Rutgers: Initial Experiences and Outcomes. In *Proceedings of the 49th ACM Technical Symposium on Computer Science Education* (pp. 1075-1075). ACM.

Yin, R. (1994). *Case study research: Design and methods (2nd ed.).* Thousand Oaks, CA: Sage Publishing.

Zumbrunn, S., McKim, C., Buhs, E., & Hawley, L. R. (2014). Support, belonging, motivation, and engagement in the college classroom: A mixed method study. *Instructional Science*, *42*(5), 661-684.

Zweben, S., & Bizot, B. (2018). 2017 CRA Taulbee Survey. *Computing Research News*, *30*(5), 1-47.

Appendix A

Individual Interview Protocol for WiC at Northwestern

Basic information:

What is your major and which year are you now?

Previous computer science experience:

Were you interested in CS in high school?

Did you take any AP CS class?

What did you want to do for your career when you were in high school?

WiC experiences:

How long have you been in WiC?

How did you hear about WiC and how did you start participating in WiC events?

What kind of WiC events have you participated? (can elaborate on each event that the person has been in)

How often do you attend WiC events?

Have you ever sought out help from others in WiC? If yes, why did you do that? If no, what prevented you from doing that?

Do you think WiC helps with your learning in CS? If yes, in what way?

Do you think you belong to the larger computer science community? Why?

What part of WiC worked in increasing your sense of belonging, and what can be done to improve?

Do you think your identity has changed through your participation in WiC? If yes, in what way?

WiC leadership and organizational decisions:

Why did you decide to become a leader?

What did you envision to to accomplish for WiC?

What decisions did you make to develop the community culture? How they decide on these?

What changes have you seen over the years with respect to women's representation in the field of computer science?

What challenges and obstacles did you encounter in terms of increasing women's representation in computer science?

What support and help did you receive from the department and the school as you fought for the diversity?

Appendix B

Reflection Form for WiC Executive Meeting

Your name and role

What did you accomplish in today's meeting?

What did you learn today?

What is the most meaningful discussion today?

What is unresolved/what needs more discussion today?

What is your plan to make WiC a better organization?

Appendix C

Sense of Belonging Survey

Answer the following questions about *what Computer Science is like for you*. Indicate the extent to which you agree or disagree with each statement using the scales below. Please use the whole range of each scale. 7-point Likert scale from strongly disagree to strongly agree.

I belong to Computer Science.

I feel comfortable in Computer Science.

Other people understand more than I do about what is going on in Computer Science.

I think in the same way as do people who do well in Computer Science.

It is a mystery to me how Computer Science works.

I feel alienated from Computer Science.

I fit in well in Computer Science.

Compared with most other Computer Science students, I am similar to the kind of people who succeed in Computer Science.

Compared with most other students, I know how to do well in Computer Science.

Compared with most other Computer Science students, I get along well with people in Computer Science.

What is your major?

What school are you in?

Which year are you now in school?

How did you know about WiC? (Facebook, Email, Friends, Other)

How long have you been in WiC? (Less than 3 months, 3-12 months, 1-2 years, more than 2 years)

What is your role in WiC?